EVALUATION OF 1978 REHABILITATION SITES AND EROSION CONTROL TECHNIQUES

REDWOOD NATIONAL PARK

WATERSHED REHABILITATION

TECHNICAL REPORT 1

APRIL 1980

AN EVALUATION OF 1978 REHABILITATION SITES
AND EROSION CONTROL TECHNIQUES IN
REDWOOD NATIONAL PARK

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Arcata, California
April 1980

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AND EROSION CONTROL TECHNIQUES

SUMMARY

This report evaluates initial results of the 1978 rehabilitation program after one winter season. The first winter is probably most critical for testing erosion control structures with high water flows. A cost analysis of erosion control techniques, as well as a critique of contracting methods, is provided. Initial results of revegetation efforts are cursorily examined; however, a full report on survival must necessarily wait until the stress of a hot, dry summer on the vegetation is evaluated.

Redwood National Park was expanded by 48,000 acres through Public Law 95-250 in March, 1978. About 33,000 acres of the expanded park had been logged during the past 10 to 20 years. As part of expansion, Congress mandated implementation of a watershed rehabilitation program. Redwood National Park initiated the program to help correct erosion problems and to help return parklands to a mimic of their natural condition.

Rehabilitation techniques were tested on five sites totalling about 230 acres during 1978. Each area contained typical problems found throughout parklands in the watershed and a number of factors were weighed in choosing the sites. Severity of damage varies with age and type of logging along with a host of natural factors. Problems are most significant on tractor logged clearcuts adjacent to perennial streams in highly erosive tributary basins. Other factors such as site location and accessibility play important roles in selecting an area. In addition, Redwood Park's ability to correct problems using known technology without causing new, serious damage also helps determine if a site will be restored immediately or delayed a few years.

Results of work on the five sites are summarized in Table 1. Although specific rehabilitation prescriptions varied from site to site, a combination of heavy equipment and work crews were used to correct erosion problems.

In general, heavy equipment work and erosion control structures used on rehabilitation sites effectively reduced serious erosional problems during the first winter season. Heavy equipment was used for large earthmoving tasks. A dragline effectively removed uncompacted, unstable or oversteepened road fills in road prisms, in stream crossings and in

TABLE I

SUMMARY OF 1978 REHABILITATION PROJECTS

SITE	ACRES/ROAD LENGTH	HEAVY EQUIPMENT		WORK CREWS	
		Hours	Cost	Hours	Cost
1. Upper Miller Creek	80 acres/ 4000 feet	140	$14,422.00	3800	$43,000.00
2. Emerald Creek	90 acres/3170 feet	66	$ 2,760.00	2900	$53,557.00
3. Upper Bond Creek	51 acres/Not applicable	157	$ 6,025.00	4430	$19,503.00
4. Lower Bond Creek	Not applicable/ 1500 feet	8	$ 320.00	320	$ 3,685.00
5. C-Line Landing	2 acres/ Not applicable	32	$ 1,760.00	400	$ 3,740.00

log landings, thus apparently preventing mass slope failure in those areas. Backhoes excavated crossroad drains to direct water from seeping cutbanks across the road prism, and redirected diverted drainages into natural channels. Backhoes also cleared streams of organic and inorganic debris, and removed culverts. Crawler tractors accomplished several tasks including disaggregating rocked road surfaces, outsloping excavated road fill material, pulling organic debris from unstable areas, and excavating crossroad drains.

Based on one season's observation, heavy equipment was used too conservatively on 1978 rehabilitation projects. Some drainages should have been excavated deeper to prevent subsequent downcutting in the channels. More crossroad drains should have been constructed in some areas to better drain sites. All former logging haul roads accessible to caterpillar tractors should have been disaggregated by ripper teeth.

Contracts between Redwood Park and heavy equipment operators to rent machinery and operators (equipment rental agreements) seem to be advantageous to the Government in terms of cost, efficiency, job quality, and flexibility to changing project needs.

Work crews under contract with the National Park Service constructed erosion control structures after equipment work was completed. Waterbars diverted runoff from skid trails. Checkdams controlled downcutting in gullies and stream channels. Water ladders and flumes conveyed water across steep, erodible slopes. Willow wattles, a combination of a biological and physical barrier to rilling, were used extensively on disturbed slopes. Planter boxes trapped loose sediment on steep ravelling slopes or in narrow chutes created by debris slides. Gully plugs controlled headcut retreat by armoring the headcut and preventing further downcutting of the gully knickpoint.

Crossroad drains conveyed water across road prisms, preventing water flow down the road alignment and reducing soaking and oversaturation of road fill.

Energy dissipators at the outlet of check dams, water ladders and crossroad drains protected bare earth from erosion.

Grass seeding, stem cuttings of sproutable species and mulches also inhibited soil erosion in specific areas. Winter maintenance of these structures appears essential to deal with unanticipated drainage problems on the sites and assure adequate protection of slopes and drainages through high rainfall periods.

I. INTRODUCTION

Redwood National Park was established by P.L. 90-245 in 1968 to preserve significant examples of primeval coastal redwood forests and the streams and seashores with which they are associated. The Park's redwood forests include the world's tallest measured tree along with several others nearly as tall on alluvial flats adjacent to Redwood Creek. From the moment of Park creation, timber harvesting and road construction disturbances in the Redwood Creek watershed outside the park combined with natural processes to pose imminent threats to Park resources. Interactions between inherently unstable, highly erodible hillslopes, exceptionally severe storms and intensive land use practices caused Redwood Creek and many of its major tributaries to transport far more sediment than natural.

Roughly 90% of the forests in Redwood Creek basin have been logged since 1945. Logging practices greatly accelerated erosional processes (Janda, 1975). Changes include increased runoff, a general modification of the natural hydrologic regime, increased sediment yield, and accumulating sand and silt deposits in major stream channels. Other problems such as increased landsliding, filling and widening of stream beds, erosion of stream banks, damage to streamside vegetation, and overall degradation of natural aquatic ecosystems have been documented (Nolan, 1976; Harden, 1978). Primary causes of these harmful changes include vegetation removal, pervasive alteration of hillside drainages, development of an extensive logging road network, and construction of thousands of miles of tractor log skidding trails.

Congress, in establishing Park boundaries in the 1968 Act, had not anticipated the magnitude of adverse impacts resulting from continued logging in the watershed upstream from Parklands. In 1978, Congress amended the Redwood National Park Act through P.L. 95-250 to enlarge the Park by 48,000 acres (75 mi^2). It also mandated preparation and implementation of a watershed rehabilitation program aimed at accelerating erosional recovery of lands within Redwood Creek basin, thereby eventually diminishing threats to Park resources.

In the summer of 1978, rehabilitation began on five sites within the Park (Figure 1). The sites represent a range of geologic, hydrologic, vegetative and soil conditions on logged-over lands. Sites were chosen to allow experimentation with various rehabilitation techniques. The general approach on each site included detailed geomorphic mapping to delineate erosional problem areas, use of heavy equipment for major earthmoving tasks to rectify drainage diversions and clear stream channels of debris, use of work crews to construct erosion control structures and replant disturbed areas, and photographic and survey documentation of rehabilitation efforts.

II. GENERAL DESCRIPTION OF AREA

Redwood Creek drains a 280 square mile watershed in the mountainous, coastal region of Northern California. The headwaters begin near elevations of 5000 feet and the creek flows north-northwest to the Pacific Ocean near Orick, California. Through most of the Parklands, Redwood Creek follows the trace of a major geologic structure, the Grogan Fault, which divides the land into two different terrains. The basin's westside is underlain by well-foliated, mica-quartz-feldspar schist, and generally has steeper hillslopes, a more clay-rich soil and a higher drainage density than the east slope. In contrast, the east side is primarily underlain by pervasively sheared sandstones and siltstones and it supports more gentle slopes, loamy soil, locally large earthflow prairie areas, and a lower drainage density. Physical characteristics of each rehabilitation site are described later.

Mean annual precipitation for Redwood Creek basin is 80 inches and mainly occurs in storms from November through March. The 1978-1979 precipitation, however, was 33% below average (Geological Society of America, 1979; Janda, 1975). From November, 1978, through August, 1979, five storm events occurred, and the largest 24-hour rainfall was 2.2 inches. In contrast, normal 24-hour rainfall (occurring once every two years) is 4.5 - 6 inches of rain (Janda, 1975). Even though total precipitation in the 1978-79 season was below normal, storms that did occur provided a test of the effectiveness of erosion control techniques.

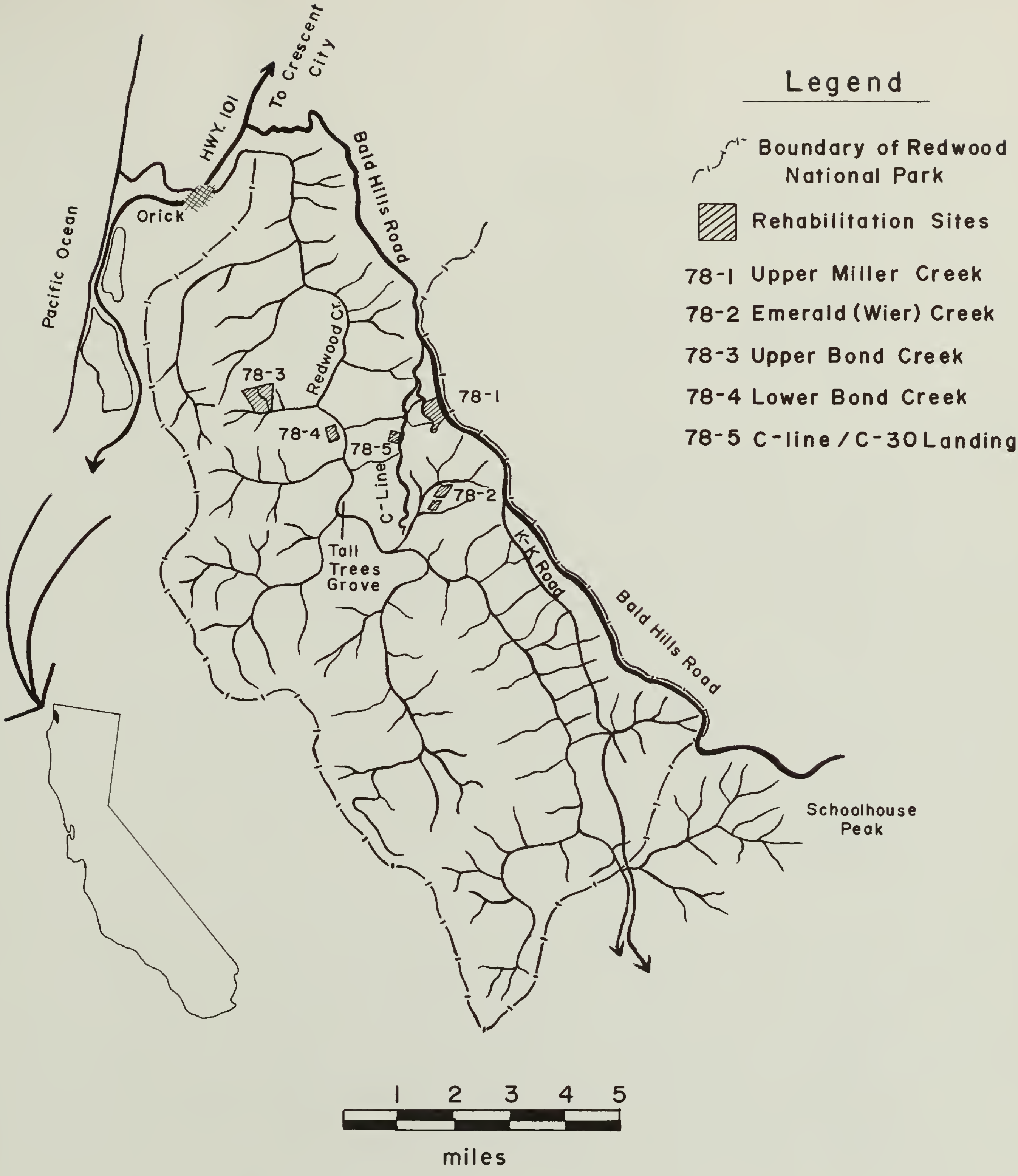


Figure 1: Location map of 1978 rehabilitation sites, Redwood National Park

III. 1978 REHABILITATION PROJECTS

A. Introduction

Park lands modified by previous logging vary in severity of damage and erosional problems. The decision to rehabilitate a site and what type of methods to use depend on a number of factors including extent of damage, age of logging, and significance of erosion.

Some sites are so altered, little can presently be done to ameliorate changes. Examples of problems are large, deep-seated mass failures along stream channels which periodically contribute large amounts of sediment to the fluvial system. Our present state of knowledge in treating most of these areas is inadequate. Revegetation is difficult and of doubtful value in treating the deep-seated source of the problem. Site access frequently is a monumental logistical problem and may create even more erosional problems.

Other sites are not significant threats to Park resources. Here, the problems lie in revegetating compacted sites, such as stable roads and landings, or in treating minor erosional problems in advanced second growth forest stands. However, creating access through a vigorous stand of young trees may cause more damage than the original problem, and these sites may be left alone. If revegetation of small areas is not necessary for erosion control, treatment will be delayed or the area may be left to recover naturally.

Finally, some sites pose serious threats yet are treatable within present technology. Sites, such as landings, unstable road fills, and stream crossings, potentially may fail and contribute large quantities to streams. Some have already failed, while others show evidence of instability and will fail in the near future. Problems may be large, but they are within the capacity of cranes, backhoes and other heavy equipment to repair. Erosion control techniques have already been used to address these problems. Although experimentation will improve these techniques, the basic technology exists for treating these problems.

The rehabilitation program's present stage is focusing on treatable sediment problems in the Redwood Creek basin. A variety of techniques are possible on each site. For example, a road may be completely outsloped (Figures 2 and 3), fill material may be completely removed and redeposited on more stable terrain, or the road surface may simply be decompacted and planted. Similarly,

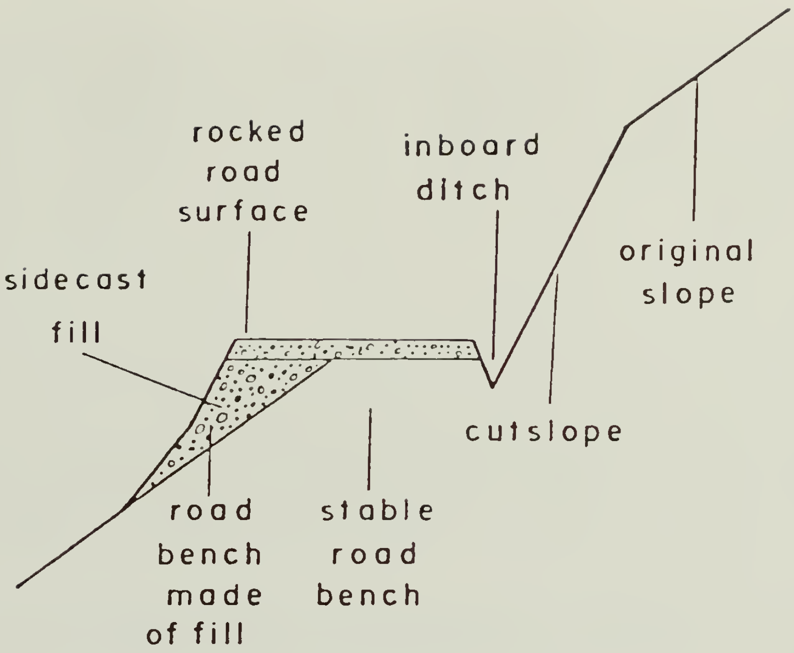


Figure 2: Typical logging road in cross-section.

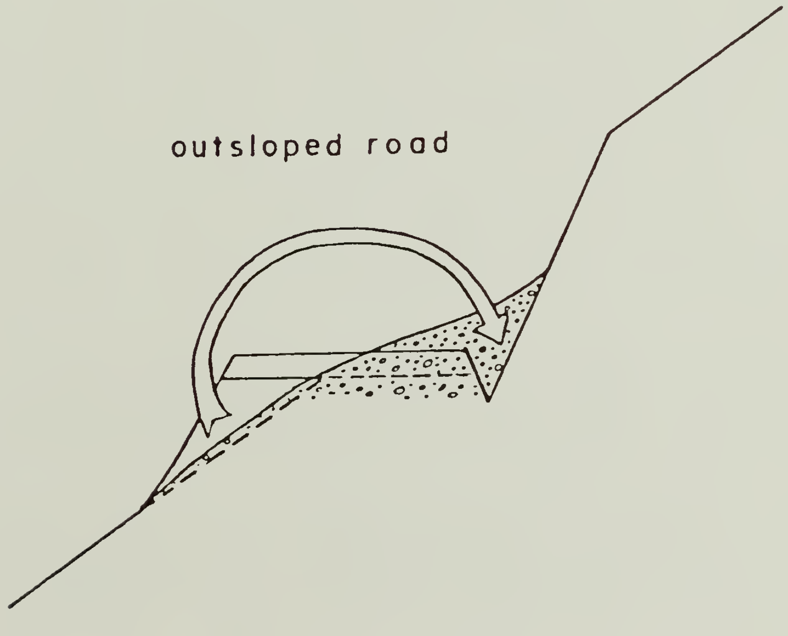


Figure 3: Slope configuration across logging road after heavy equipment transfers fill and grades on outslope.

a landing may be outsloped completely, it may be dewatered by the construction of drainage ditches, or perched organic and inorganic debris from its edge may be pulled back to a more stable location. Treatment depends on severity of problems, site accessibility, and type of problems adjacent to the site in question. In some cases, a potentially unstable area will be purposely left alone to observe effects of non-treatment.

B. Geomorphic Mapping and Planning of Rehabilitation Sites

Detailed geomorphic maps were prepared for all rehabilitation units prior to any earth-moving or revegetation work. To accomplish the mapping, a recent aerial photograph of each site was enlarged to a scale of approximately 1:1800, secured to a board, and a sheet of mylar attached as an overlay.

Surface drainage patterns including natural and modified features were mapped. In many cases, skid and haul roads disrupt natural drainage networks, concentrating runoff via inboard ditches and culverts, onto slopes which previously carried little or no runoff. Rapid channel erosion resulted, while at the same time some established channels carried reduced flows. Active and inactive channels and rills and gullies were mapped.

Roads constructed across small drainages form small, earth fill dams, blocking stream channels. Streams continue to erode and gully fill material. In addition, saturated fills could collapse and cause destructive debris avalanches. Approximate volume of fill material, degree of channel banks revegetation, relative stability of adjacent slopes, drainage area upstream of the fill crossing, and accessibility of the site were all noted on the map. These factors, along with debris failure potential, helped determine if the fill crossing would be removed.

Since road cutbanks frequently intercept ground water, locations of emerging ground water were indicated on the map and flagged in the field. These were considered potential sites for building diversion structures such as crossroad drains.

Roads frequently become gully courses after logging unless runoff was diverted off the roads by waterbars. If waterbars existed, their success or failure was noted and maintenance needs were compiled. If new waterbars were needed, the location was mapped.

Potential and active slope failures triggered by road construction, logging-related disturbances or stream erosion were also mapped. Drainage diversions, gully stabilization, removal of unstable material and site revegetation were considered during mapping.

Once mapping was completed and severity of erosional problems was evaluated, an approach to site rehabilitation was outlined, taking into consideration both roads and adjoining upslope areas. Types of equipment to be used in large earth-moving tasks were chosen, and estimates of time necessary to complete heavy equipment work were made with the help of equipment operators.

Equipment with operators was rented by the National Park Service under equipment rental agreements. National Park Service staff supervised heavy equipment operation.

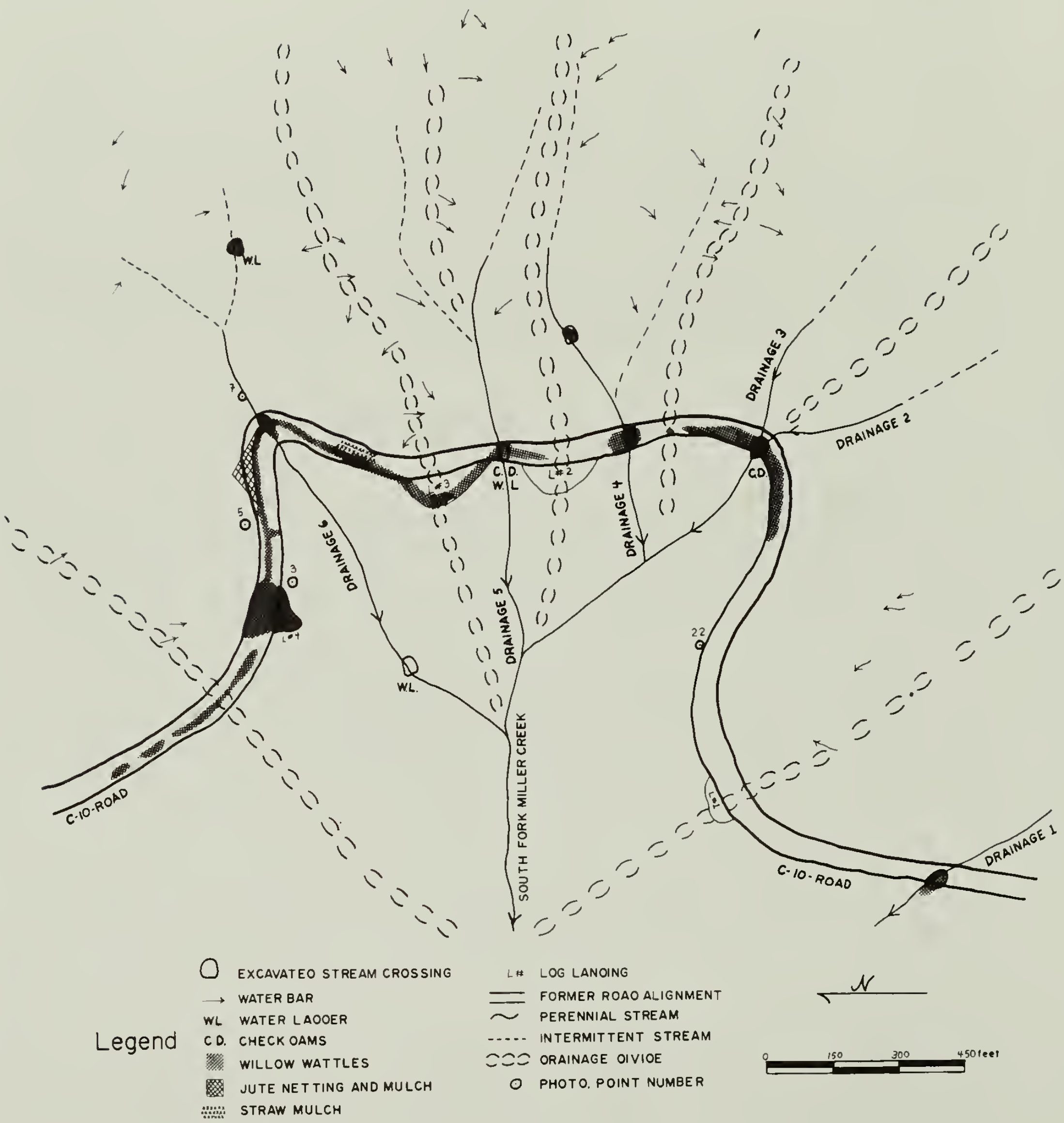
C. Upper Miller Creek Rehabilitation Test Site 78-1

Site Description

The upper Miller Creek rehabilitation test site includes 60 acres at the headwaters of the South Fork of Miller Creek. Arcata Redwood Company clearcut and tractor-yarded the area from 1970 through 1972. Geologically, the site is underlain by fractured and faulted lithic arenites (greywackes) with minor amounts of thin-bedded argillites and conglomerates. Hillslopes are dry and generally moderate (20-40%) on upslope portions of the site and steepen (50-65%) on downslope portions, especially below the C-10 road. The C-10 road is a rock-surfaced logging road that provides access to the Miller Creek rehabilitation site.

By 1978, the C-10 road had been abandoned for six years and had disrupted natural drainage patterns, creating major erosional problems. Water was concentrated in the inboard ditch with only a few culvert outlets leading from the ditch. Water from culvert outlets discharged into channels that may have accommodated less flow prior to road construction. Cutbanks intercepted subsurface flow, and skid trails diverted runoff down trails and roads. Because revegetation was not occurring on the road alignment and infiltration was poor on the compacted surface, rainsplash erosion and gullying were prevalent. As a result of the above disturbance, surface runoff probably increased over natural conditions. In addition, the road contributed sediment into stream channels from fill slope failures, from failing stream crossings and from washouts.

UPPER MILLER CREEK REHABILITATION TEST SITE



Site Map 1

Approach

160 acres were mapped geomorphically on Miller Creek in 10 days in June, 1978. Of that area, only 80 acres showed erosional problems that warranted treatment, and most rehabilitation work was done on a few acres along the C-10 road alignment. The site and work accomplished is shown on the following Upper Miller Creek Rehabilitation Test Unit map.

The major task on this unit, "pulling" the C-10 road, was done in September, 1978, and took 13 days to complete. Figures 4 through 7 show the sequence of heavy equipment work. Initially, the road was decompacted (ripped) by a D-8 caterpillar tractor to increase infiltration. Then a dragline crane excavated sidecast fill material and deposited it along the inboard edge of the road adjacent to the cutbank. A crawler tractor outsloped this material to a gradient of 5 to 20% to prevent ponding or concentration of runoff. Stream crossings on the C-10 road were excavated by dragline to approximately resemble pre-road channel gradient and streambank configuration. In addition, a few fill crossings on skid trails which disrupted drainage patterns above and below the C-10 road were removed and streambanks were recontoured.

Cost for heavy equipment work on the Miller Creek Unit was $14,500 or 25% of the total cost of unit rehabilitation (labor and equipment combined). A total volume of 10,000-12,000 cubic yards of material were excavated and reshaped, representing a cost of $1.20-$1.45 per cubic yard of material. Cost and time details for heavy equipment are listed in Table 2.

After heavy equipment work was completed, a contract was let to Aero-Marine Research, Inc. for labor-intensive erosion control work. Major contracted tasks were building checkdams and water ladders in potentially unstable drainages, constructing willow wattles on steep, unprotected slopes, building waterbars on skid trails, and planting cuttings of sprouting species on unvegetated banks. A full description of erosion control techniques is given in Section IV. Total labor costs for work on this site was $43,000, and 3800 person-hours were utilized. A breakdown of cost and time is listed in Table 3. Costs and times were obtained from contractor's work sheets and may not reflect true distribution of time or costs for the site; however, they are the best estimates available. In January, 1979, a National Park crew of four to six people planted 1020 redwood and 1080 Douglas fir containerized seedlings on areas disturbed by heavy equipment (about 4 acres). Materials for restocking Miller Creek cost $170.00 (8¢ per seedling) and approximately 100 person-hours were needed for the task.

Figure 4: Most logging roads are surfaced with eight to twelve inches of rock and must be disaggregated to promote infiltration and revegetation. Here, a D-8 Cat decompacts the C-10 road with its ripper teeth.

Figure 5: Because of its long reach, a dragline crane is used to lift unstable side cast road material and organic debris to the road bench.

Figure 6: Excavated fill is piled along the inboard edge of the road and against the road cut bank. A tractor grades the fill to achieve a gentle outslope on the former road alignment.

Figure 7: A dragline crane removes fill from a stream crossing and reshapes channel banks to a more stable configuration.

UPPER MILLER CREEK

TABLE 2: COST PER EQUIPMENT TASK

TASK	EQUIPMENT	APPROXIMATE TIME (HRS)	TOTAL COST	COST PER MILE
Equipment work: preparation and supervision		150 person-hours		
Rip 4000 ft. of C-10 Road	D-8 Cat ($75/hr)	4	$ 300	$ 400
Outslope 2000 ft. of pulled road	D-8 Cat	4	300	
	D-6 Cat ($50/hr)	14	700	
	Dragline ($60/hr)	43	2,580	9,000
Remove C-10 road fill crossings from Drainage #1:				
1	D-8 Cat	4	300	N/A
2 & 3	D-8 Cat & Dragline	4 ea	540	N/A
4	D-6 Cat & Dragline	3 ea	330	N/A
5	D-6 Cat & Dragline	3 ea	330	N/A
6	D-6 Cat & Dragline	11	1,210	N/A
Remove skid road fill crossings #1:				
1	D-5 Cat ($40/hr)	3	120	N/A
2	D-5 Cat	4	160	N/A
3	D-5 Cat	5	200	N/A
Pull back log landing				
3	D-6 Cat & Dragline	13 ea	1,430	N/A
4	D-6 Cat & Dragline	24	2,640	N/A
Miscellaneous Road Work	All of the above		1,655	N/A
			$12,795*	$17,000/mi

Transportation costs:	Dragline	$ 382.50
	D-8 Cat	610.00
	D-6 Cat	400.00
	D-5 Cat	300.00
		$1,692.50

Equipment Rental Cost: $14,487.50

UPPER MILLER CREEK, 10/78 - 1/79

TABLE 3: LABOR INTENSIVE WORK

TASK	QUANTITY	CONTRACT UNIT PRICE/TASK	PERSON-HOURS/ TASK
Field mapping of geomorphology	160 acres	N/A	80
Contract preparation		N/A	115
Contract supervision		N/A	200
Transportation of:			
people	3-4 man crew		546
materials			145
Organization of personnel			125
Discussion with Contracting Officer			33
Preparation of:			
split wood			185
cut willows			448
Wattles: Cut and bundle installation	85,915 ft^2	$370-$380 per 1000 ft.	17 hours/ 1000 ft^2
Check Dams	24 dams	$76.70/dam	16.5 hours/ dam
Sprig Planting	20,550 ft^2	$80/1000 ft^2	6.2 hours/ 1000 ft^2
Waterbars:			
construction	31 bars	$29-$35/bar	3 hours/dam
repair	68 items	$14-$30/repair item	1.5 hours/ item
Planter Boxes	14	$20/box	
Water Ladder	1 (21 ft. long)	$15/1 ft. length	
Excavate Cross Road Ditch	1 (30 ft^3)	$42/ditch	90 hours
Fertilize & Grass Seed	4 acres	$75/acre	
Mulch and secure with jute netting & sprigs	3300 ft^2	$185/1000 ft^2	unknown
Straw mulch and secure with sprigs	4000 ft^2	$255/1000 ft^2	unknown
Planting conifer seedlings	1020 redwood 1080 Doug. fir	$0.08 per seedling	100
TOTALS FOR CONTRACT:		$43,000.00	about 3800 person-hours

Documentation

A qualitative and quantitative monitoring program was developed to evaluate immediate changes on the site due to rehabilitation work and to monitor future changes on recently modified slopes and channels. Several types of documentation were used. Twenty-five cross-sections perpendicular to the C-10 Road and to six stream crossings were surveyed by theodolite. In addition, two tag-line cross-sections were established on the largest tributary. Cross-section analysis yields an estimate of the volume material removed by heavy equipment. Survey reproducibility ranges from good to excellent; generally error is $\pm$ 0.2 feet. Longitudinal profiles for disturbed reaches of three streams were also surveyed. In addition, time-sequential photographs were taken from 32 permanently established photo points to visually document site changes. Photo points are marked by tagged wooden or rebar stakes, and the locations are shown on site Map 1. Surveys or photographs will be repeated in the future to document the gradual recovery of rehabilitation sites through time.

The following photos illustrate use of heavy equipment in rehabilitating the Miller Creek Unit. Sequences of before and after treatment photos are also shown. If photos were taken from a permanently established photo point, the photo point number is noted as "PP#. . . . . . ." below the photographs.

Effectiveness of Heavy Equipment on Miller Creek

Six stream channels were cleared of fill along the C-10 Road. Nearly vertical banks were pulled back to a 25-30% slope, and no large bank failures occurred during the first winter. The largest channel, D6, had 1100 cubic yards removed from a road crossing. Under natural conditions, channels were almost straight; however, excavation generally decreased sinuosity slightly and channel gradients increased slightly (from 0 to 3%).

Channels were excavated to the estimated original streambed level. In three cases, excavation was not deep enough and streams downcut 6 to 18 inches during the winter (Figure 18). As the streams downcut, a lag of rocks collected and began to armor the channel bed, inhibiting further downcutting. Channel bed stabilization is important because downcutting undercuts the toes of slopes, resulting in streambank failure. Checkdams were needed to prevent vertical incision in some channels.

Figure 8: PP5a 8/22/78
Before photograph of former culvert in Drainage 6. Culvert became plugged with debris and winter flows washed out about 800 cubic yards of road fill into the stream channel.

Figure 9: PP5a 10/9/78
After photograph of Drainage 6. Dragline crane pulled back vertical banks to a more stable configuration, and a cat tractor outsloped the fill material removed by the crane.

Figure 10: PP7 8/22/78
Before photograph of culvert washout in Drainage 6, close-up view looking downstream. Note person in channel for scale.

Figure 11: PP7 3/12/79
After photograph of Drainage 6. Newly excavated channel exhibiting more gentle banks. Note rows of willow wattle installed on both banks.

Figure 12: PP3 8/22/78
Before photograph of oversteepened edge of log landing. Some fill material and organic debris have already failed downslope. In addition, water continued to pond on the landing, and tensional cracks suggested future failure of the hillslope.

Figure 13: PP3 3/12/79
After photograph of log landing. Edge of landing has been pulled back and fill material was outsloped. Drainage of runoff from the landing has been improved. Willow wattles were planted on the steep slopes below the former landing.

Figure 14: PP5c 8/22/78
Before photograph of abandoned haul road with unmaintained inboard ditch and steep fill slopes. Landing at right of photo shows perched debris beginning to fail downslope.

Figure 15: PP5c 10/9/78
After photograph. Inboard ditch has been eliminated. Steep road fill has been pulled back and outsloped. Perched debris on landing has been removed, and the landing itself has been outsloped to improve drainage. Slopes have been willow wattled and partly mulched with straw.

Figure 16: PP22b 8/22/78
Before and after sequence of a rocked haul road that was disaggregated (ripped) by a D-8 cat tractor to promote revegetation and infiltration of runoff. Note the paucity of vegetation on the compacted road surface even following 5 to 7 years of non-use.

Figure 17: PP22b 10/9/78

The C-10 Road was outsloped with fill material placed along the inboard edge of the road. The road's cross-sectional gradient changed from nearly level prior to rehabilitation to 20 to 25% after outsloping. The most extreme outsloping occurred where a large quantity of excavated material needed to be relocated and end-hauling of the material was not practical. Here the newly formed slope was 40-45%, which approaches the angle of repose of the material. However, the slope is dry, drains well, and the material has settled with no signs of slope instability.

Where fill material was potentially unstable (as indicated by tension cracks, incipient scarps, or buttresses of rotting organic debris), material was excavated and redeposited on stable ground. No tension cracks reappeared, and no slope failures occurred in excavated areas.

Outsloping caused no major drainage problems on the road alignment; however, ponding water occurred where the road was outsloped less than 5%. This was especially a problem on large landings. In future work, cross ditches should be excavated on landings to drain these areas more efficiently.

Organic debris (slash) from unstable landings was incorporated into outlsoping material placed on the road. Except for some minor settling, slash has not adversely affected outsloping. However, as decomposition of the material occurs, drainage patterns on the outsloped road may be changed. If possible, burying organic debris in outsloped roads should be avoided in the future.

Groundwater seepage from cutbanks occurred in locations not recognized as problem areas in the summer months. Minor rilling and slumping occurred in these areas. These problems could have been avoided if the area's hydrology had been mapped during the wet season.

Equipment work improved drainage patterns on cutover slopes above and below the C-10 Road. Road fill prone to mass failure was removed from stream channels. Water flow diverted out of its natural drainage by tractor logging (skid trails, lay outs, etc.) was redirected into its original channel. Infiltration capacity of compacted soil increased locally by "ripping" as evidenced by lack of standing water in treated areas that previously held a large amount of ponded water.

Decompaction by tractor rippers also promoted revegetation of the road alignment. On sample sites with similar conditions,

Figure 18: Drainage 5 in the Miller Creek Unit. Downcutting occurred in channel that was cleared of debris and road fill. The channel was not protected by an armor of rock prior to downcutting, although a lag of rocks is now beginning to form on the channel bed.

an unripped section of road had only a trace of fescue (Festuca occidentalis) growing upon it. In contrast, an adjacent plot that had been ripped exhibited a 10% ground cover composed perennial rye (Lolium perene) - 5% ground cover; bluegrass (Poa spp.); velvet grass (Holcus lanatus); hairgrass (Aira caryophyllea and Deschampsia elongata); dogtail (Cynosurus echinatus); soft brome (Bromus mollis); nitgrass (Gastridium ventricosum) and others. Rye and velvet grass had been seeded by work crews; other species invaded the road alignment naturally.

Effectiveness of Vegetation on Erosion Control

Upper Miller Creek was broadcast seeded with a mix of 50% annual and 50% perennial rye grass at an application rate of approximately 40 pounds per acre in January, 1979. A small amount of other commercial seed was included in the grass mix. Ammonium sulfate fertilizer (20-0-0) was applied at a rate of 100 pounds per acre. Grass germinated about a week after seeding, but ground cover was generally sparse and uneven, ranging from 0 to 30%. Rain on bare soil carried seed downslope, where it was caught on wattle terraces. Terraces now show the heaviest concentration of sprouting grass. Raking the soil after seeding may inhibit downslope movement of seeds. Heavy grass seeding should be accomplished immediately following heavy equipment operations when soils are loose and generally uncompacted. The first heavy fall rains tend to settle the soil structure and close the open pore spaces near the surface, reducing seed bed quality.

Tanoak (Lithocarpus densiflorus) acorns, chinquapin (Castanopsis chrysophylla) seeds, sedge Carex sp. seeds, alder (Alnus rubra) seeds, Juncus effusus seeds, Rumex crispus, seeds, maple (Acer sp.) seeds, and Baccharis pilularis seeds were planted in mid-December. All species, with the exception of alder and maple, showed some sprouting success in spring, 1979. Willow wattles were planted October through December, 1978. Stem cuttings of willow (Salix spp.), thimbleberry (Rubus parviflorus), coyote bush (Baccharis pilularis), Rhododendron macrophyllum, Ceanothus spp., and elderberry (Sambucus callicarpa) were planted in the same period. Planting in autumn (the dormat season) results in the best survival rate; however, little erosion control benefit accrues then. Root strength and leaf cover from brushy or grassy species develops little during the first winter season.

Wattle terraces (when greater than 6 inches wide) effectively trapped silts and fine sand carried downslope by sheetwash. A 3-foot vertical spacing of wattle rows seems to work well.

Rills seldom start between wattle rows and if they do begin, rills are intercepted by the next wattle row downslope. In addition to dispersing water, wattles probably increased infiltration rates on treated areas by providing a regularly spaced porous medium on slopes.

Locally, vigorous sprouting of grasses and Juncus formed a strong root mat and trapped vines from upslope. In general, however, slope material became armored by pea-sized gravel particles. Finer particles were mobilized by rainsplash impact and transported downslope by sheetwash. Sheetwash occurs on unvegetated, somewhat compact outsloped roads. Rainsplash pedestals up to one-half inch high are evident on sparsely vegetated slopes. Rainsplash impact compacts previously "ripped" material, and fines loosened by rainsplash clog "pore" spaces in the top layer of soil. As a result soil infiltration capacity decreases and surface runoff may increase from a site. Some immediate ground protection on disturbed soils is needed to prevent rainsplash, sheetwash and rill erosion from removing the fine fraction of soil material, and to protect the porous structure of decompacted material. Mulches are the best candidates to provide immediate ground protection.

D. Emerald (Harry Wier) Creek Rehabilitation Site 78-2

Site Description

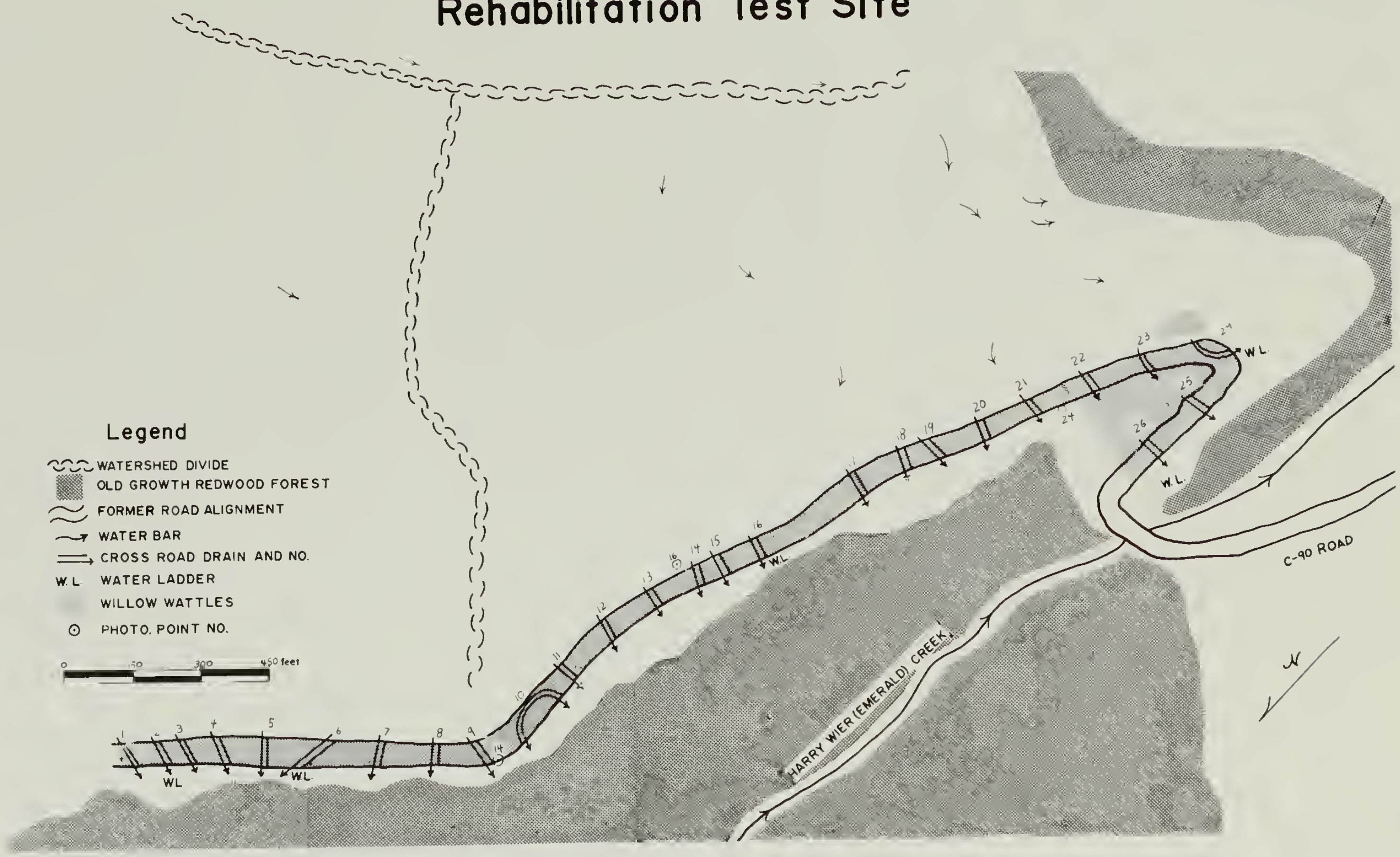
The Emerald (Harry Wier) Creek rehabilitation unit is located on a wet, lower slope adjacent to Emerald Creek. The C-90 Road, a 0.7 mile dead-end logging spur road, forms the unit's downslope border. Two tractor-yarded cut blocks, separated by a thin leave strip of old growth trees, total 60 acres of logged timberland above the C-90 road. Three landings were built along the road.

A major structural feature, the Grogan Fault, transects the unit. The fault trends north-northwest and separates unmetamorphosed Franciscan sandstone and siltstone on the east side of Redwood Creek from Franciscan schist on the west side of the basin. This fault transects the beginning of the C-90 Road, creating extremely sheared bedrock. The combination of a lowerslope, wet locality and the sheared bedrock results in severe slope stability problems at this site directly adjacent to Emerald Creek. Soil within the unit is derived from highly foliated schistose rocks (Masterson and Orick soil series) and sheared siltstones and sandstones (Hugo soil series). Regolith in the downslope portion of the unit is clay-rich and wet throughout much of the year.

Arcata Redwood Company constructed the C-90 Road in 1975, and logged the two cutblocks by 1976. The C-90 Road showed signs of massive instability soon after it was built and a number of mitigation measures were attempted to control slope instability. Sandbags were placed along the road's inboard ditch to buttress ditch banks against collapse and to keep ditch flow off the adjacent road surface (Figure 25). The North Coast Regional Water Quality Control Board also required construction of small check dams and drainage structures to help abate erosion along the road. These measures failed after one winter and were ineffective.

Mass slope instability and severely altered drainage patterns caused by road construction and tractor-yarded logging were major concerns at this site. Failing cutbanks filled the inboard ditch and caused surface runoff to be diverted across the road, resulting in development of rills and gullies. Saturated areas along the road threatened stability of road fill. In addition, natural drainage patterns were disrupted by placement of five culverts leading from the inboard ditch and by some diversions caused by tractor disturbance on the hillslopes. A buffer strip of old growth redwood left on steep slopes bordering Emerald Creek was threatened by major mass movement features along the road upslope.

Harry Wier (Emerald) Creek Rehabilitation Test Site



Approach

Site mapping was accomplished in late spring, 1978 and a case 580-C backhoe and D-8 caterpillar tractor began work in late summer. Heavy equipment work was confined to the road alignment. Initially, the entire road was ripped by the D-8 tractor. Five culverts were removed and crossroad drains were excavated and reshaped in former culvert locations (Figure 19). In addition, drains were built across the road in 21 areas where cutbanks intercepted ground water flow. (Figure 20). Where possible, the backhoe and cat tractor outsloped the road to improve drainage. Work accomplished is shown on the following Harry Wier (Emerald) Creek Rehabilitation Test Site Map. Equipment work took about seven days to complete and was finished by early October, 1978. Equipment cost $2,760; details are listed in Table 4. 470 cubic yards were excavated from crossroad drain sites and 580 cubic yards were moved in the outsloping operation. Total costs were $2.63 per cubic yard of material excavated.

After the road was outsloped and cross drains were excavated, a contracted labor crew lined crossroad drains with rock, constructed water ladders or other energy dissipation devices downslope of crossroad drains, planted willow wattles and cuttings on unprotected slopes, constructed waterbars on tractor yarded slopes and did necessary shovel work to refine heavy equipment work. In addition, a trail was built to improve access to the site when the ground was wet and muddy. A horse was used to transport willows to different work projects on the site. Several local cooperatives did the work in a joint effort, or partnership. Total labor cost was $53,560.00 and 2900 person-hours were utilized. A breakdown of cost and time is given in Table 5. A full description of techniques used on this site are listed in Chapter IV.

In January, 1979, a five-person National Park crew planted 923 redwood and 125 Douglas-fir containerized seedlings at a cost of 8¢ per seedling, or $150.00 for the site. Approximately 100 person-hours were used for replanting.

Documentation

Three types of documentation were established on the Emerald Creek site to evaluate changes through time. A longitudinal road profile covers 90% of the pulled portion of the C-90 Road. It is a fairly accurate portrayal of the road alignment. (± 0.2 feet). Twenty-six cross sections were surveyed across the C-90 Road to monitor changes in slope topography before and after road outsloping by heavy equipment. Particular features (for example, swales) are well-defined by several

EMERALD CREEK

TABLE 4: COST OF EQUIPMENT TASK

TASK	EQUIPMENT	APPROXIMATE TIME (HRS)	TOTAL COST	COST PER MILE
Equipment work: Preparation and Supervision		105 person-hours		
Rip 3170 ft. of C-90 road	D-8 Cat ($75/hr)	3	$ 225	$ 320
Construct 4 crossroad drains	D-8 Cat	13	975	
Remove 5 culverts and Construct 22 crossroad drains	580-C Backhoe ($30/hr.) and 580-C Backhoe	52	1,560	
			$2,760	$ 320

Cost per mile of road based on above work costs: $3,950.

EMERALD CREEK, 10/78 - 12/78

TABLE 5: LABOR INTENSIVE WORK CONTRACT

TASK	QUANTITY	CONTRACT UNIT PRICE/TASK	PERSON-HOURS/ TASK
Geomorphic mapping of site			40
Contract preparation			100
Contract supervision			65
Transportation of:			
people	± 16 man crew		237
materials			47
mill			13
Organization of personnel			70
Discussion with Contracting Officer			45
Preparation of:			
split wood			400
milling wood			70
gathering brush & rock			74
Wattles: cut & bundle installation	8,375 ft.	\$2.95/ft	0.05 hrs/ ft.
Sprig Planting:			
sprig preparation & sprig planting	232,200 ft^2	\$42.99/1000 ft^2	2.12 hours 1000 ft^2
Waterbars:			
construction	8	\$227 each	3.6 hrs/bar
repair	5	\$179 each	2.4 hrs/bar
Water ladder	4	\$730 each	40.5 hrs/ ladder
Trail construction		\$1,100	162
Rocking cross drains	20	\$373 each	2.05 hrs/ drain
Shovel work		\$1,583	133
Dissipators	20	\$147 each	3.9 hrs/ dissipator
Grass seed	3 acres	\$54.50/acre	11
Tool Maintenance			21
Documentation			57
Planting conifer seedlings	923 redwood 125 Doug. fir		
TOTALS FOR CONTRACT:		\$53,557.06	2,900 person-hrs

cross-sections while more uniform sections of the road have fewer cross-sections. The profile survey was also used to construct a planimetric map of the rehabilitated portion of the road. The map was then used to compute the total material from the C-90 Road.

Twenty-seven permanent photo points were established on the Emerald Creek site. Photographs were taken of all work sites before heavy equipment work, after equipment work, and after labor-intensive work was completed.

The following photos illustrate the use of heavy equipment in rehabilitating the Emerald Creek site. Sequences of before- and after-treatment photos are also shown. If photos were taken from a permanently established photo point, the number of the photopoint is noted as "PP # . . . . . ." below the photographs. Locations of the photo points are given on Site Map 2.

Effectiveness of the Heavy Equipment Work

The objective at Emerald Creek was the elimination of the C-90 Road as a barrier to surface runoff by outsloping the road and constructing crossroad drains (CRD's) to conduct water across the former road alignment. Work on the unit prevented concentration of runoff downslope and saturation of the disturbed zone along the former road. Crossroad drains worked with varying degrees of success. Outsloping of the road generally worked well and the slopes drain freely.

Of 26 crossroad drains constructed on this unit, 22 were excavated by backhoe. The uppermost four drains (CRD's #1-4) were built by a caterpillar tractor. All CRD's were later improved by hand labor under contract; but, backhoe-constructed CRD's required less improvement. Both types of drains effectively directed water across the former road surface.

Nineteen CRD's were rocked to prevent downcutting. Because the C-90 Road had been rocked between CRD's #10 and #26, a good supply of coarse rock was available nearby. Rock sizes between 3 and 15 inches in diameter were used. Rocking was definitely effective, especially where large rock (above eight inch intermediate diameter) made up at least one-third of the rock blanket. Finer bed material lodged in between the large rocks to a protective channel bed armor.

Figure 19: A backhoe excavated and removed culverts from the C-90 road, and smoothed out the resulting trough to form a cross road drain with gently sloping banks.

Figure 20: To prevent runoff from concentrating in the inboard ditch, cross road drains are excavated along the C-90 road by a backhoe.

Figure 21: PP16a 8/23/78
C-90 road prior to rehabilitation is showing signs of instability. Small cut bank failures are blocking the inboard ditch. Note the scarp of a road fill failure behind the person at the left of the photo.

Figure 22: PP16a 10/1/79
C-90 road after rehabilitation. The road has been decompacted, road fill has been pulled back, and the material has been outsloped. Note the rocked cross drain behind the people, and the rows of willow wattles on the outsloped road.

Figure 23: PP24 8/23/78
Before and after sequence of culvert removal and road outsloping. A backhoe excavated a cross road drain in the former culvert location.

Figure 24: PP24 3/19/79

Figure 25: PP16c 8/23/78
C-90 road prior to rehabilitation. Sandbags line the unstable inboard ditch of the rocked haul road.

Figure 26: PP16c 3/19/79
After rehabilitation, C-90 road has been decompacted and outsloped, and the inboard ditch has been filled in. Surface runoff now crosses the removed road through cross road drains rather than concentrating and flowing along road alignment.

Figure 27: PP19b 8/23/78
Before and after sequence showing removal of road and construction of cross road drains on a portion of the C-90 road.

Figure 28: PP19b 3/19/79

Figure 29: PP14d 8/23/78
Prior to rehabilitation, log landing is truncated by the scarp of a major failure. **Culvert is no longer operational.**

Figure 30: PP14d 3/19/79
After rehabilitation, culvert has been removed and cross road drains have been constructed to drain surface runoff from the site of the failure. In addition, a drainage ditch was dug at the toe of the cut banks to direct runoff into cross road drains. The deep-seated failure was not addressed except through upslope drainage diversions.

Geomorphology and surface water sources of the unit were mapped in late spring when most seepage areas were no longer active. Most areas of seepage or flow were successfully identified. However, in a few cases seepage problems were not apparent during mapping or heavy equipment work and groundwater emerging the following winter was not channelized through cross road drains, causing rilling, gullying, and slope stability problems (see discussion of CRD's numbers 10, 11, 12 and 13 below). At the mouth of CRD 23, seepage was purposely allowed to disperse across an outsloped section of the road. Because the amount of flow was small and the slope was wattled, rilling did not occur downslope of CRD 23.

In some cases, portions of the inboard ditch were kept open to intercept several rills and seep areas and to direct this flow into one crossroad drain. This technique decreases the number of crossroad drains necessary on a road, and it worked well as long as the crossroad drain's catchment area remained small and the portion of road was stable. However, crossroad drains #10, 11, and 12 were apparently spaced too far apart (100 feet) because two slumps occurred at this site (Figure 31). Also the slope in the vicinity of these CRD's is unstable. Perhaps more drains in this area would have further dewatered the slope above the CRD's and prevented slumping. Slope wetness, potential amount of emerging groundwater from cut banks and surface runoff channels must be considered while planning spatial distribution of drains.

During the season's first two storms, the road between CRD 12 and 13 received unanticipated runoff. After these early storms, ditches were manually dug to drain the slope. Along this section of road, noticeable tension cracks contour the slope. Along this section of road, noticeable tension cracks contour the slope, and a series of three step scarps indicate that a slump block dropped 6 to 15 inches during the winter. The area was still wet in early June, and this incipient slump will probably continue to fail in the future. Perhaps ditches could be dug deeper and steeper across the road to ameliorate poor drainage in this area. However, much of the water entering the area is undoubtedly derived from subsurface flow, and surficial ditches will not treat the problem. For example, a contour ditch built to drain into CRD 11 did not prevent a small slump block from failing in that area.

Slope problems in the vicinity of CRD's 10-13 involve mass slope failure, and techniques of road outsloping and construction of drains cannot be expected to solve such slope

stability problems. It must be recognized that not all erosional problems can be treated by rehabilitation methods employed on this unit.

Ditching at CRD's 12 and 13 in response to unanticipated runoff from the cutbank and adjacent slope after the first rain definitely helped minimize surface erosion. This well-timed ditching is a good example of the great need for winter maintenance during first major storms (as well as throughout the winter) to repair and modify troughs and structures so they will function. On this unit, a day of ditch-digging during the first storm saved thousands of dollars worth of willow wattling and recontoured road surface and prevented major washouts of some recently outsloped road sections.

Another area of instability along the C-90 road was the middle landing. Prior to any rehabilitation work, tension cracks, pull-apart scarps, and rotational slumps on the slope above the landing indicated obvious slope instability. Stabilizing this landing would have been a major heavy equipment effort. Removing all perched fill would have necessitated rebuilding the C-90 road for crane access, using the crane to pull back debris, end-hauling the debris, and yarding out many large logs. In any case, these measures may not have stabilized the slope because of the deep-seated nature of the instability. Therefore, a decision was made not to stabilize the landing. Trenches were dug at the upslope end of the landing in an attempt to divert water from the landing surface, but the shallow gradient of the trenches prevented water from draining effectively. During the winter following rehabilitation work, the landing continued to fail and the slump block on the outer edge of the landing dropped six feet in early 1979 (Figure 32). The scarp from this rotational failure truncates the rock energy dissipator of CRD 10.

In comparison to the middle landing, the uppermost landing also had a large amount of perched debris at its edge, which was not removed. This portion of the road was not as inherently unstable as the middle landing. Here the crossroad drains divert flow onto more stable areas, and no movement occurred during the winter.

Effectiveness of Vegetation on Erosion Control

Willow wattles were built on most pulled road surfaces and on outsloped fill materials. Wattle terraces trapped sediment ranging from silts and clays to material 12 millimeters in

Figure 31: April, 1979.
A small slump occurred on a recently wattled slope in an area with few cross road drains.

Figure 32: April, 1979.
The outside edge of a landing failed where instability had previously been seen (see Figure 30 for comparison). The man's hand points to a cross road drain that has been truncated by the scarp of this failure.

diameter (Figure 34). Few rills developed on wattled slopes, whereas they are more prevalent on similar slopes that are bare and unwattled.

A mixture of 50 percent annual rye grass seed and 50 percent Potomac orchard grass was broadcast seeded on the C-90 Road alignment in late autumn, 1978. The application rate was approximately 40 pounds/acre. The grass cover was not uniform over the unit (0 to 30% ground cover). Locally, thick stands of rye have trapped fine sediment from upslope. Where grass forms a thick mat along the sides of cross road drains, the amount of lateral erosion in the channel is a few inches less than along ungrassed reaches of the drain. Grass is not effective in inhibiting downcutting in channels, however.

Sprigs were planted on bare slopes to eventually provide ground cover and a strong root mass. As cuttings grow, their roots will increase shear strength of slope material and may eventually decrease mass movement activity. However, it will take several years before ground cover or a strong root mass is formed. Figure 36 shows that a small slump occurred on a cutbank which was sprigged to prevent that problem. Most other cutbanks showed little movement last winter. On these stabler slopes sprigs may survive to increase resistance to failure.

Stem cuttings of willow (*Salix sp*) showed 99 percent sprouting success in terms of new branches as of June, 1979. However, only 50 percent of *Baccharis pilularis* var. *consanguinea* stem cuttings were sprouting.

Figure 33: Willow wattles have sprouted vigorously on moist slopes on the Emerald Creek Rehabilitation Unit. Willows were planted 7 months before this photo was taken. Grass cover is sparse (1-2%).

Figure 34: Terraces upslope of willow wattles trap fine grained soil particles which are carried downslope by runoff. The wattles impede downslope soil movement and surface rilling by providing a physical barrier to runoff.

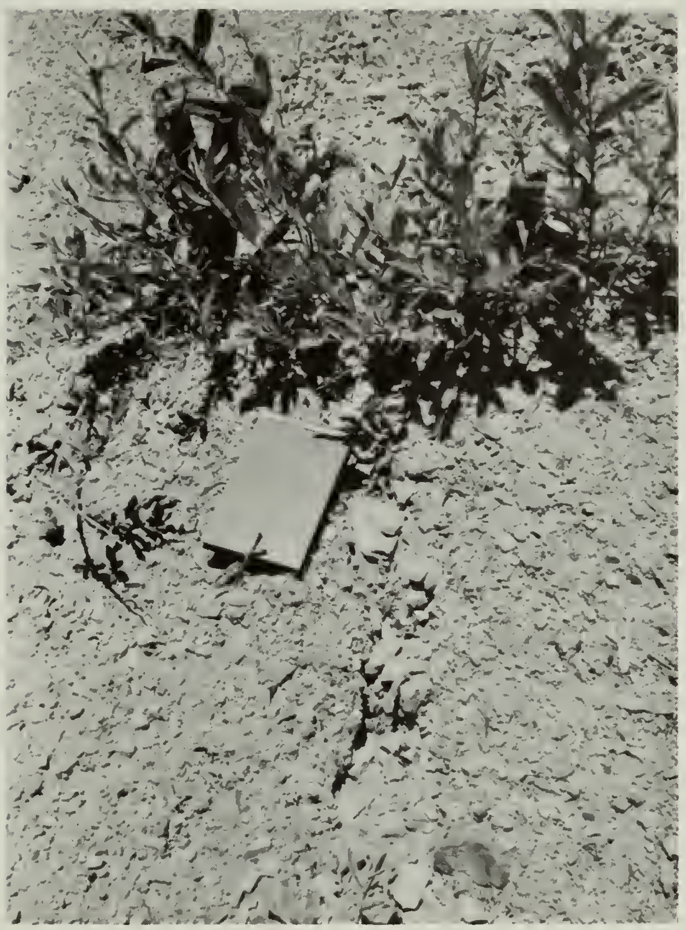


Figure 35: Although willow wattles can disperse small amounts of runoff and impede rilling, they are less effective when subjected to concentrated runoff. Here, a rill beginning upslope of a wattle row carries enough runoff to undercut the wattle and continue rilling downslope.

Figure 36: Slump in a cut bank that had been planted with willow stem cuttings a few months earlier. The young sprouts have not yet established an extensive enough root mass to prevent slumping. Note remaining stem cuttings to the left of the center of the photo.

E. Upper Bond Creek Rehabilitation Test Site 78-3

Site Description

The Upper Bond Creek Rehabilitation Unit includes approximately 51 acres of cutover land near the headwaters of Bond Creek. The site is underlain by well foliated, highly deformed and fractured schists of the Franciscan formation. Locally, more competent "blocks" of schist protrude from the slope as resistant outcrops.

Schist bedrock weathers to form clay-rich loams of the Orick and Masterson soil series. Regolith derived from schists is generally deeper, redder, finer-grained and more cohesive than regolith derived from sandstone. Schist mechanically breaks down into finer, more weathered fragments than sandstone, and clay is a common weathering product of schist minerals. Infiltration capacity and subsurface drainage are rated as good, and soils are moderately susceptible to surface erosion. (Iwatsubo, 1976).

Elevation ranges from 750 feet at the lower end of the unit to 1050 feet at the top of the unit. Slopes within the unit average 40% and range from 15% within the central bench to over 85%. Steepest slopes are encountered immediately above the L-1-5 road along six well incised stream channels. The six drainages originates several hundred feet above the L-1 Road and traverse the unit. In addition, four streams are fed by perennial springs within the rehabilitation area, and in total, nearly 5000 feet of incised stream channel are contained within the unit.

For the most part, slopes are relatively dry and stable. At the unit's base, emerging groundwater along steeper slopes locally caused shallow soil failures to develop. Clay rich soils and deep road cuts along the L-1-5 Road aggravated this problem.

Incised, cobble-bed stream channels within the unit respond quickly to storm rainfall. The high clay content of local soils together with steep drainages (20%-50%) and channel side slopes (40%-85%) contribute to rapid runoff.

Louisiana-Pacific Corporation clearcut and tractor yarded the area from 1975 to 1976. Four to six foot diameter redwood dominated the original stand with lesser amounts of Douglas-fir in the overstory. The sub-canopy included scattered

hemlock and tanoak while huckleberry, rhododendron, salal and ferns were common ground cover plants. In the fall of 1976, remaining vegetation and slash was intensely burned to aid in site preparation and replanting.

Stream protection and equipment exclusion zones were not provided for any of the perennial or intermittent streams in the harvest area. As a consequence, each stream channel was heavily impacted during yarding operations and shade canopy was obliterated by broadcast burning following logging.

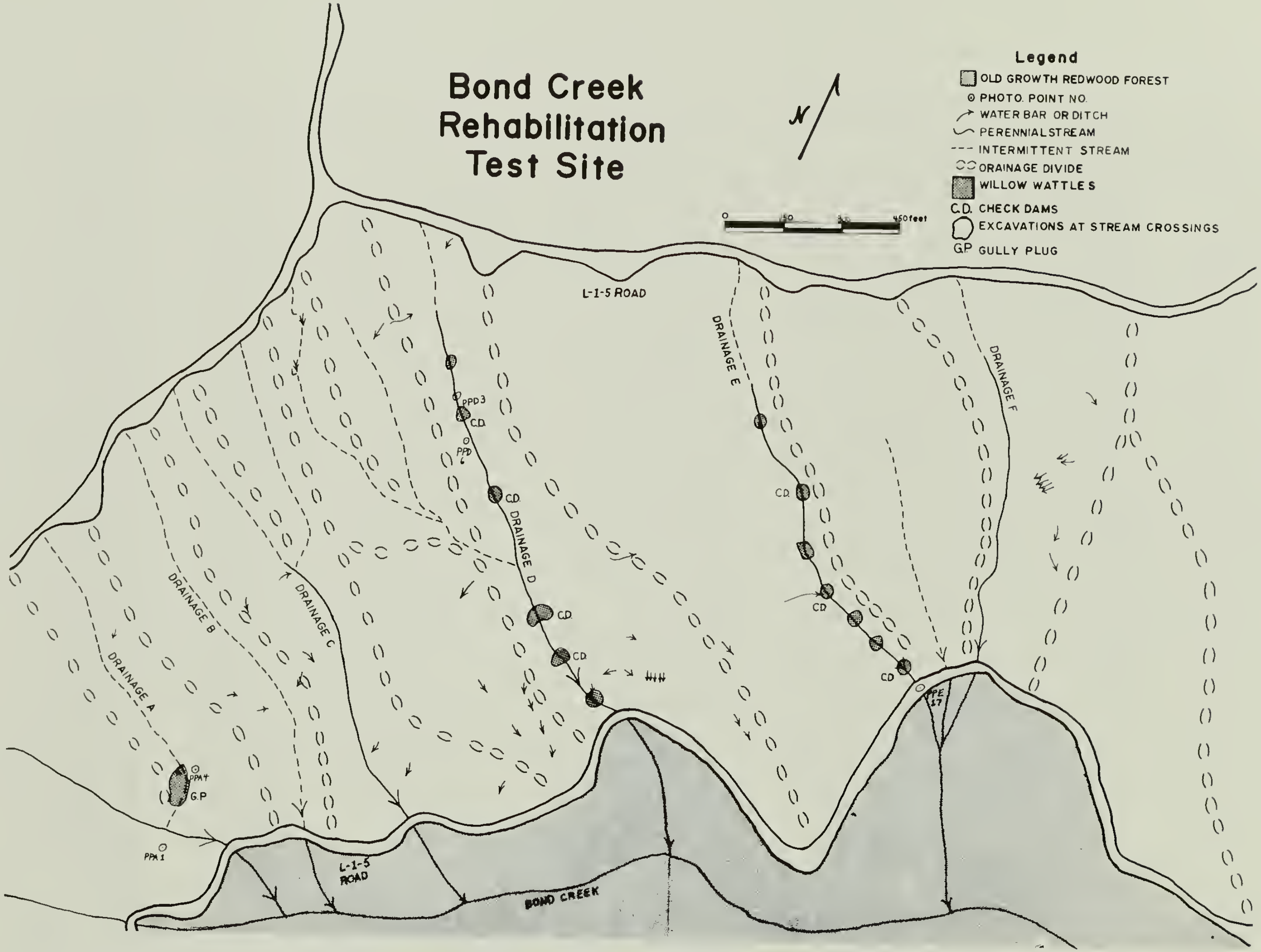
In 1978, approximately 70 - 80% of the area consisted of relatively barren skid trails and other regions of exposed mineral soil. Where tractors crossed incised stream channels, up to 15 feet of road fill and logging slash were pushed directly into watercourses, disrupting natural drainage patterns and contributing large volumes of sediment to the stream system. Severe gullying of skid trail crossings occurred in the two years since logging.

Virtually every intermittent and ephemeral stream channel had been used as a path for skidding logs down to the L-1-5 Road. Although fill crossings are generally absent on these watercourses, their entire lengths contained large areas of exposed soil. Diverted watercourses also triggered several landslides and initiated gully systems elsewhere on the hillslope.

Rehabilitation efforts were concentrated around streams where bare soil in or adjacent to channels was continually subject to excessive rates of erosion. Restoring natural drainage networks and removing inorganic and organic debris from watercourses were the main problems addressed. In addition, improperly placed waterbars, gully head cuts, small slope failures and numerous bare soil areas were treated. As work progressed, it was decided to leave three drainages alone for eventual comparison with the treated streams. As a result, the rehabilitation site was reduced to roughly 51 acres from the original 85 acres and incorporated 14 of the 28 stream crossing sites.

Approach

Detailed geomorphic mapping of the 85 acre plot was accomplished over five days in early July, 1978. Work accomplished is shown on the following Bond Creek Rehabilitation Test Site map.


Bond Creek
Rehabilitation
Test Site
N
0
150
300
450 feet
Legend
OLD GROWTH REDWOOD FOREST
PHOTO. POINT NO.
WATER BAR OR DITCH
PERENNIAL STREAM
INTERMITTENT STREAM
DRAINAGE DIVIDE
WILLOW WATTLES
C.D. CHECK DAMS
EXCAVATIONS AT STREAM CROSSINGS
G.P GULLY PLUG
L-1-5 ROAD
DRAINAGE A
DRAINAGE B
DRAINAGE C
DRAINAGE D
DRAINAGE E
DRAINAGE F
PPD3
C.D.
PPD
G.P
PPA4
PPA1
CD
PPE
L-1-5
ROAD
BOND CREEK

Site Map 3

After work prescriptions were formulated, heavy equipment cleared drainages of organic debris and roadfill sidecast material. A D-5 caterpillar tractor winched logs from skid trail stream crossing sites and pushed as much material as possible to either side of the watercourse so it could not re-enter the channel. A Case 580-C Extend-a-hoe (rubber tired backhoe with extended reach) followed the tractor and excavated the bulk of the remaining soil from the fill prism. This excavated material was then back-bladed down the skid trail away from the stream and used to outslope the tractor trail approaches.

Equipment completed excavations in about nine days in early September. Of the tractor's work time, roughly 80% was spent winching debris while actual stream channel excavations (blade work) consumed less than 20% of machine hours. A small portion of winching time was spent waiting while chokers were maneuvered around the logs or while the backhoe uncovered buried debris. In addition, a limited amount of time was allocated to the backhoe for waterbar construction to establish cost comparisons with manual installation. Final equipment expenses amounted to $6025. Table 6 outlines equipment work details and costs for the site.

Time constraints required development of hand-labor erosion control contract before equipment work was completed. This methodology, also followed on Upper Miller and Wier contract sites, made it difficult to describe and define proposed work items. As a result, several change orders and changes in amount were required after the contract was awarded.

Three bids were received for the described work. They ranged from a low of $23,660 to a high of $57,930. Aero-Marine Research of Arcata, California was awarded the contract which involved waterbar repair and construction, ditch digging, wattling, sprig planting, checkdam construction, hand grass seeding and fertilization, special planting and gully-plug construction. Work was accomplished between October, 1978, and January, 1979, for a total work time of approximately 4430 person-hours. Itemized person-hours and unit prices for each of the tasks are depicted in Table 7. Final cost, after all change orders, amounted to $19,500. Specific erosion control techniques are evaluated in a later section.

BOND CREEK

TABLE 6: COST PER EQUIPMENT TASK

TASK	EQUIPMENT	APPROXIMATE TIME (HRS)		TOTAL COST
Construct 15 waterbars	Extend-a-hoe ($30/hr)	1		$ 30
Remove fill and reshape crossing #	Extend-a-hoe ($30/hr) & D-5 Cat ($40/hr)	Hoe --	D-5 Cat	
7L	"	5	6	390
7K	"	5	6	390
7J	"	8	6	480
7I	"	4	3	240
7H	"	9	15	870
7G	"	2	3	180
7Q	"	2	2	140
7P	"	2	2	140
7O	"	2	2	140
7N	"	12	13 1/2	900
7M+1/2	"	3	2	170
7M	"	1	2	110
7M-1/2	"	6	10	580
7 A+C	"	7	14	770
Miscellaneous		2.5		75
Transportation costs:	extend-a-hoe		$ 60	
	backhoe		300	
	D-5 Cat		150	
			$510	510
Total equipment rental cost				$6025

BOND CREEK, 10/78 - 1/79

TABLE 7: LABOR INTENSIVE WORK CONTRACT

TASK	QUANTITY	CONTRACT UNIT PRICE/TASK	PERSON-HOURS/ TASK
Transportation: of people	2-15 person crew		802
of material to site			82
of material on site			204
Organization of Personnel			346
Discussion with Contracting Officer			141
Preparation of: splitwood			292
willows			372
Wattles: installation	4341 ft.	$1.00/ft	0.1 hr/ft
Sprig planting:			
preparation			64
planting	31,067 ft^2	$80/1000$ft^2$	9.1 hr/1000 ft^2
Check Dams	128 dams	$45/dam	5 hr/dam
Waterbar: construction	12 bars	$30/bar	4.7 hr/bar
repair	10 items	$15/rpr.item	1.6 hr/item
Excavating ditch	105 ft.	0.85/ft	0.6 hr/ft
Grass seed and fertilize:			
broadcast seeding	51 acres	$43/acre	
test seeding	14 plots	$20/plot	242
Gully Plug	1	$768	84
Pack Animals	7 animals		60
Miscellaneous			88
Tool Maintenance			172
Conifer planting			
TOTALS FOR CONTRACT		$19,503	4430 person-hrs.

Documentation

Cross sections were surveyed with a theodolite at seven cleared stream crossings and at one fill failure. The channels were surveyed before and after heavy equipment work. Planimetric maps of stream crossings were drafted and the volume of material excavated from the crossings was computed. The reproducibility of the cross-section surveys was excellent; generally error was within $\pm$ 0.1 feet.

Permanent photo points were established at 58 locations in the rehabilitation unit to visually monitor changes in treated and untreated stream crossings. Photographs were taken before and after equipment work, and after the labor contract was completed.

Effectiveness of Heavy Equipment on Upper Bond Creek

The primary emphasis on this unit was excavation of large volumes of debris previously in well-incised, steep stream channels at 14 tractor crossings. High channel gradient, flashy stream response, and unconsolidated fill material combined to yield excessive erosion rates and stream channel sedimentation. While only a relatively small percentage of each fill had gullied in the two years since logging, large quantities of potentially unstable material remained. Excavating this sediment would thereby reduce potential long-term sediment yields.

Fourteen stream crossings were excavated at an average cost of $393 (range: $140 to $870). Combined equipment time per crossing averaged just over 11 hours for the tractor and back-hoe working in concert. Where detailed surveys could be applied, volumes of material removed from fill crossings were computed at a unit cost of $4.12 per yard (n=5). Sixty-two percent of that cost was expended on tractor work while the backhoe accounted for the remaining 38 percent.

Prior to excavation, streams were stair-stepped over each tractor crossing (no culverts or other drainage structures had been installed). Water surface gradients over the upper surface were less than 5% while flow spilled over outside fill surfaces generally over 50% in steepness. Following stream clearance, mean channel gradient through nine excavated areas averaged 31% (range = 25% to 37%). The length of stream channel impacted by rehabilitation averaged 56 feet and varied from 20 feet at one small crossing to over 90 feet at a more heavily disturbed site.

At each tractor crossing, channels were excavated to the estimated original stream bed level. Rounded cobbles, rotten organic debris and changes in soil characteristics

were indicators of the former stream bed and banks. In several instances, fills were not excavated to this level if it was judged that excessive side slope gradients, or other potential unstable conditions would exist following stream clearance. In addition, several stumps pushed into the channels during logging were too large to remove with the D-5 winch. As will be discussed later, most of the excavated channels were protected from further erosion by the installation of check dams. However, even those which were not protected showed little scour (less than 6 inches), over the first winter.

Slopes adjacent to stream channels were originally quite steep (about 80%). Excavation of each stream crossing necessitated reconstruction of these steep slopes with bare, relatively loose soil. The backhoe bucket was used to grade and tamp newly placed soil but slopes appeared highly susceptible to erosion. Fortunately, winter rains helped compact and settle loose side-slope material and no failures or significant surface erosion has occurred.

In a number of instances, skid trail approaches to stream crossing sites were originally constructed (excavated) across slopes in excess of 70%. Soil material sidecast along these approaches frequently spilled into adjacent stream channels. These oversteepened fill slopes were gullied, showed little sign of revegetating and often displayed fresh tensional cracks along the skid road surface; eventual failure in many cases was inevitable. Where these scarps were fed by seeps and springs emanating from the skid trail cutbank, complete failure had occurred or was imminent.

Each oversteepened, potentially unstable access skid trail was outsloped by the backhoe as it completed work in the stream channel and backed its way out of the crossing. Outsloping entailed excavating fill material along the outside of the road surface and replacing and compacting it along the cutbank. Runoff generated on former trail surfaces or in upslope areas then flowed directly across the recontoured slope rather than down the road. Areas of emerging groundwater were not covered over with loose fill material.

Since outsloping, no slope failures have occurred. Areas where tensional cracks and small scarps were previously located show no signs of renewed activity. No new failures have developed. Initial results suggest that excavation,

even if only partially completed, unloads the slope sufficiently to stabilize fill slope instabilities. This appears to be an effective method to prevent the future introduction of soil material into adjacent stream channels. However, surficial soil erosion from these sites must be controlled to prevent gullying on steep, bare slopes.

Elsewhere on slopes within the unit, the backhoe was used to install a number of waterbars which, by tradition, are done by tractors. For comparative purposes a number of waterbars were also constructed by hand. The backhoe was able to excavate waterbars at a rapid rate and low cost. Approximately 15 waterbars were made in one hour's time at a cost of roughly $2.00 each. Bids prices received for pick and shovel waterbar construction ranged from $30.00 to over $300.00. Use of heavy equipment is clearly less expensive. However, in other locations, limited access may prohibit use of machinery.

An important factor in backhoe work on steep slopes and in stream channels was operator skill. Apparently only a few highly skilled operators work in the Northern California area. A number of backhoes have since been rented for similar jobs and their success in accomplishing the same tasks was highly dependent on their ability to maneuver across relatively steep slopes. As a result, the time and cost figures for each task as well as the success of individual excavations elsewhere could vary substantially from the data presented in this report.

Effectiveness of Vegetation on Erosion Control

Approximately 4300 linear feet of wattling was installed. The vast majority was composed of 100% willow. Wattles were placed at roughly 3 foot vertical spacings on steep, bare sideslopes freshly disturbed by heavy equipment during rehabilitation. For the most part, wattle terraces succeeded in storing sediment derived from the steep area between it and the next higher wattle. Although no deposition pins were installed, accumulations of silts and clays in depressions are obvious.

In a number of locations, wattle terraces filtered coarse material transported to the wattle bench by rills sheetwash while dispersing concentrated flow and acting to inhibit the formation of long, continuous rill systems. However, several rows of wattles not constructed on contour collected and concentrated slope runoff along paths which now show distinct channelized erosion. If rows are not level and on contour each row will tend to collect runoff and discharge it in isolated locations onto the next wattle downslope. The cumulative effect can lead to significant rilling of bare

slope areas.

Roughly 10,040 square feet of disturbed area was planted with willow cuttings. These areas were generally confined to less steep slopes where wattling was not necessary. In addition, cuttings were also planted along stream channels below the last wattle row and within the catch basins of check dams. Gradual expansion of a root mass should aid long term stabilization of the stream bed and banks but initial benefits are limited to the immediate area surrounding each cutting.

Whipplea modesta, a creeping ground cover species, was transplanted in several locations. When established, it produces a solid mat of vines over the ground which, though untested, probably aids in controlling rilling and sheet erosion. Cuttings of individual stems had a relatively low success rate and appear to spread slowly. Transplantings of entire plants (about 1 square foot in surface area) were very successful and appear to be rapidly spreading from their central root mass. If planted in great enough density, ground cover from Whipplea modesta should aid in controlling surface erosion on harsh, dry sites where other species will not flourish.

A number of different grass species were sown over the Bond Creek rehabilitation site in January, 1979. The purpose of the seeding was to provide temporary ground protection during shrub and tree establishment. Three mixes were used, State Highway Mix (1/3 common barley, 1/3 annual rye, and 1/3 fawn tall fescue); Simpson Mix (1/3 crimson clover, 1/3 Wimmera rye and 1/3 Potomac orchard grass); and Dry Meadow Mix (1/3 perennial rye, 1/3 Potomac orchard grass and 1/3 velvet grass). The application rate specified in the contract was 40 pounds/acre, but some areas were seeded twice. Ammonium sulfate fertilizer (20-0-0) was applied at 100 pounds/acre on sites seeded with State Highway and Dry Meadow mixes while ammonium-phosphate-sulfate fertilizer (16-20-0) was applied at a rate of 200 pounds/acre to sites seeded with the Simpson Mix.

Success of the three grass mixes was difficult to evaluate because of differing site conditions on the seeded areas and uneven application. The most successful seed germination areas showed a 70% ground cover, 70% of which was composed of perennial rye (Lolium spp.). Cat's ear (Hypocherus radicata), which invaded the roads naturally, provided 5% of the ground cover. Coyote brush (Baccharis pilularis var consanguinea)

and bluebrush (*Ceanothus thrysiflorus*) seedlings were also apparent on skid trails and roads.

Dense grass cover on skid trails appears to have alleviated widespread rilling found on these sites prior to rehabilitation. However, where concentrated runoff flows down a trail, grass cover was not successful in preventing continued erosion (Figures 53 and 54).

Steep areas between wattles were frequently washed clean of seed before the seed germinated. Conversely, benches at each wattle trapped grass seed and wet conditions favored high initial success in these areas. This mat of grass helped filter coarse debris carried from upslope areas.

Red alder was broadcast seeded at approximately 10 pounds/acre on several stream crossings. Germination is evident and widespread on these stream crossings (Figure 52).

The following photos illustrate the use of heavy equipment in rehabilitating Upper Bond Creek site. Sequences of before- and after-treatment photos are also shown. If the photos were taken from a permanently established photopoint, the number of the photopoint is noted as "PP # . . . ." below the photographs. Locations of photopoints are shown on Site Map 3.

Figure 37: Organic debris that was incorporated in road fill is winched out of stream crossings by a caterpillar tractor.

Figure 38: A small backhoe is used to excavate road fill and organic debris from stream crossings. Stream banks are recontoured to achieve stable slopes. The cat in the background of the picture is winching large debris from the channel before the backhoe does the 'finish-up' work in clearing the channel.

Figures 39-44: The following 3 pairs of photographs are before and after sequences that show perennial stream channels filled with organic debris and fill material from skid roads prior to treatment. The second photo of each pair shows the same channel reach after debris is cleared and excavated and the slopes are recontoured. A small backhoe was used to clear channels, and a tractor aided in winching debris from channels.

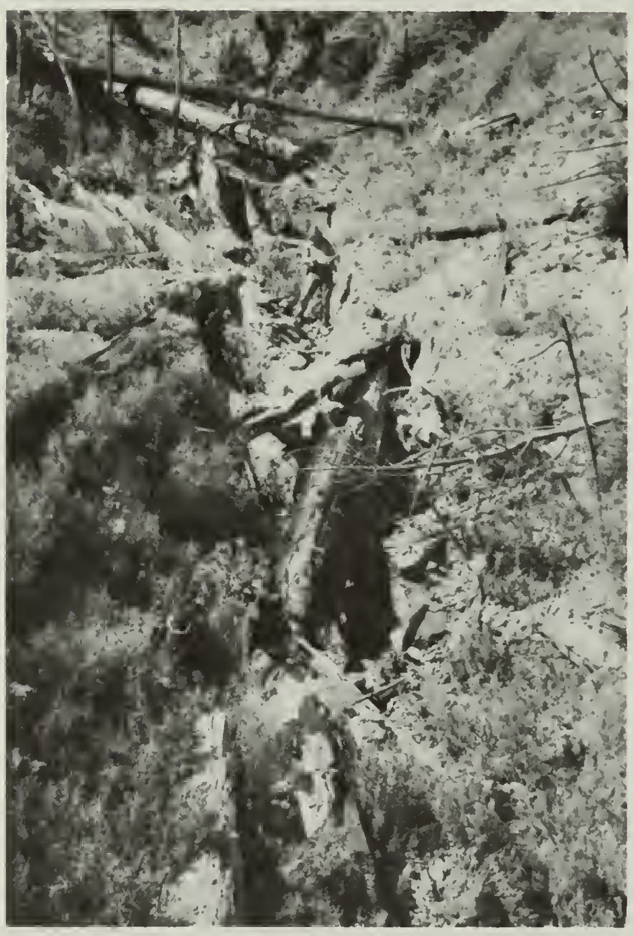


Figure 39: PPD6 9/7/78

Figure 40: 1/4/79
Stream crossing 7-K. Note series of check dams in channel and willow wattles on slope. (Note: this photo will be reshot to get the same perspective as 39).

Figure 41: PPD3 10/3/78

Figure 42: 8/79

Figure 43: PPE17 9/7/78

Figure 44: 1/4/79
Note check dams in channel, willow wattles on slope, and staggered planter boxes staked into slope.

Figure 45: PPA4 9/7/78 Prior to rehabilitation, skid road has unstable, oversteepened fill at outboard edge of road.

Figure 46: PPA4 1/4/79
After rehabilitation, perched fill has been pulled back by a small backhoe, and road was outsloped. Contour rows of willow wattles were installed just prior to this photo.

Figure 47: PPA1 9/7/78
Before rehabilitation, this site shows two parallel skid roads, the unstable fill slopes, and a gully running down the length of the photo.

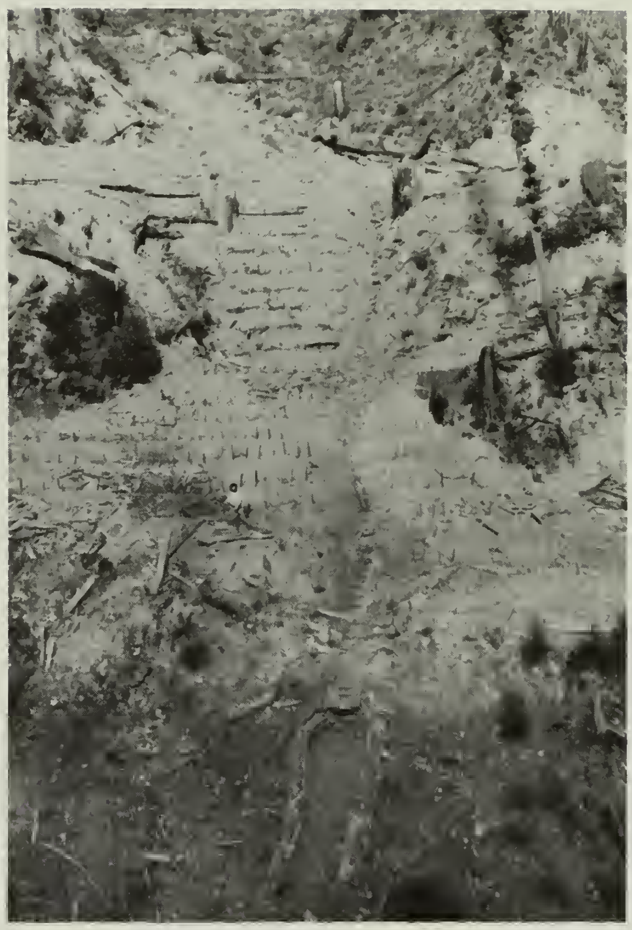


Figure 48: PPA1 1/4/79
After rehabilitation, unstable fill was removed, a small channel was cleared of debris, and slopes were willow wattled. A gully plug was installed at the headcut of a gully (lower center of photo) to prevent the headcut from migrating upstream. Details of the structure are given in Chapter IV.

Figure 49: June, 1979
Bare ground on Upper Bond Creek's recently disturbed slopes were sprig planted with willows in December, 1978 at a three foot spacing. The stem cuttings are beginning to sprout.

Figure 50: June, 1979
Close-up shot of a willow stem cutting that is sprouting vigorously. This site is damp year round.

Figure 51: Roosevelt elk and black-tailed deer browse on young willow sprouts. Nipped-off ends of sprouts are evident on this willow bundle, but generally little damage has occurred due to animal presence on the rehabilitation sites.

Figure 52: June, 1979. Young alder seedlings.
Alder seed was broadcast seeded in January, 1979, on excavated stream channel banks on the Bond Creek Unit.

Figure 53: A rill has developed on a skid road which was seeded with grasses. Under high runoff conditions and where runoff is concentrated on roads, a grass cover does not prevent rilling. Ground cover is approximately 50%.

Figure 54: June, 1979
Skid road in Bond Creek Unit with thick stand of annual and perennial ryes and other grasses. The site was broadcast seeded in December, 1978. No rilling is present. Ground cover is about 70% of which 75% is perennial rye.

Figure 55: Grass seed and fertilizer were applied at equal rates on all areas of this skid road. The moist site on the left side of the photo has a fairly good grass cover developed; survival of grass is much poorer on the drier site on the right-hand side.

F. Lower Bond Creek Rehabilitation Site 78-4

Site Description

The Lower Bond Creek Unit is located on the ridge between Forty-Four and Bond Creeks, 350 feet above the main channel of Redwood Creek. The unit is situated on a deeply weathered clay loam underlain by Franciscan schistose rocks. Hillslopes are gentle (25 to 35%) and relatively dry.

Over a mile of rocked road crosses 50 acres logged about 20 years ago, and partially relogged in the early 1970's. In general, the road is stable; however, an unmaintained culvert needed to be removed, the inboard ditch was down-cutting in several sites, and locally runoff needed to be diverted off skid trails. For the most part time had healed many early erosional problems and regrowth was well advanced.

Approach

One D-5 Caterpillar tractor with a winch worked for eight hours on this site (8 hours at $40 per hour = $320) constructing seven cross road drains, removing the culvert and reshaping the channel banks of one small drainage. The actual length of treated road was 1500 feet. Tractor work was done in early September, 1978.

From September 25th through September 28th, a crew of about ten people constructed four waterbars, ten check dams, seeded and sprig-planted bare soil in crossroad drains, and did some miscellaneous shovel work. Cost for the labor contract was $3685.

Documentation

No surveys were taken on this site, nor were any permanent photo points established. Miscellaneous photographs were taken before and during eqiupment work, during the manual labor phase, and after all work was completed.

Effectiveness of Rehabilitation Work

Crossroad drains intercepted flow from the inboard ditch and diverted it across the road into heavily vegetated areas. No drain received much flow, gradients of all the drains were gentle (less than 10 percent), and subsoil was clay-rich and quite cohesive. Thus, no downcutting occurred in drains.

Where the culvert was removed, the tractor was unable to completely excavate fill material from the stream channel. Consequently, some downcutting occurred at the lower end of

the road crossing, and further downcutting may threaten upstream check dams. An inherent weakness of using tractors for this type of work is their inability to excavate or pull material upslope.

All check dams survived winter flows well, and are still effective. Upstream-most dams filled with fine sediment. No bank failures occurred in the check-dammed reach of channel.

In late September the site was seeded with a 50-50 mix of annual and perennial ryes, at 40 pounds/acre, and ammonium sulphate fertilizer (20-0-0) was applied at 100 pounds/acre. Because the compacted road surface was not mechanically disaggregated, grass seed did not take well. Raking and fertilizing grass seed did not noticeably affect survival seed on this site. Much seed washed off the clay soils in the first few runoff events.

The site was inspected in mid-December, 1978. At that time, 236 out of 725 stem cuttings showed signs of sprouting, which represents an initial success rate of 33%. Both baccharis and willow stem cuttings were sprouting; bracken fern (Pteridium aquilinum var. pubesans) and redwood transplants also showed about 30% survival. In June, 1979, in addition to the above species, salal showed signs of sprouting. A thick carpet of young thistles invaded areas of the road surface which had been distrubed by tractor treads in the previous autumn. 57 redwood and 47 Douglas fir seedlings were planted on the road alignment in January, 1979.

Very little hillslope area in the unit was treated. Because of the second growth's advanced age and the area's relative stability, few serious problems existed off the road alignment. A few small problems, inaccessible due to revegetation, were not treated. Revegetation on the road surface was poor because of soil compaction, and in the future, treatment of similar roads should include disaggregating the road surface.

G. C-Line Landing, Rehabilitation Site 78-5

Site Description

Rehabilitation Site 78-5 is a two-acre, former landing located in the Miller Creek drainage basin on the C-Line Road. The trace of the Grogan Fault is exposed across the road from the site. Cut slopes expose the fault gouge in what appears to be rocks transitional in metamorphic grade between sandstone and schist. Soil material on the site is a sandy loam, and has a high organic content due to large amounts of slash, bark, etc, that have been incorporated into the soil.

The site was composed of compacted soil, rock, logs, and smaller organic debris. The outer edge of the landing catastrophically failed about five years ago, sending tons of sediment and organic debris into the stream channel below. In 1978, the remainder of the landing was precariously perched above the stream, and failure of more debris into the stream was imminent.

Approach

In early October, 1978, a track-mounted dragline pulled back perched debris and recontoured the slope below the landing to a more stable configuration. A D-6 Caterpillar tractor redistributed the removed fill onto adjacent stable skid trails. The machines worked sixteen hours each, for a total machine cost of $1760.

After the heavy equipment work, a contracted labor crew (Northcoast Reinhabitation Group) performed the following erosion control work between November 10th and 25th:

	Cost*
Installed 2500 feet of wattles, mixed species	$1525.
Constructed 150 feet of planter boxes	110.
Sprig planted 8000 feet^2, mixed species, upslope of planter boxes and between wattle rows	345.
	$1980.
Cost of seedlings for conifer planting (by park personnel)	16.
Total	$2000.

*These costs, based on contract bid prices, do not represent the true cost of labor and materials to the contractor. The contractor purposely bid low in order to use this site as a testing/training ground.

Total cost of rehabilitation for this site was $3740. Actual working time was about five days with crews of five to fifteen people. Park personnel seeded the entire landing with annual and perennial rye grass on December 1st and 5th, 1978, and the site was planted with conifer seedlings (70 redwood and 125 Douglas fir) in January, 1979.

Effectiveness of Rehabilitation Efforts

The crane and tractor were unable to remove all large organic debris at the toe of the landing. This debris is well keyed in, and buttresses the rest of the slope. At present it is stable; however, in time natural decomposition of the organics may lead to failure of some of the overlying material. Except for some minor settling in disturbed fill material, there are no indications at present of instability on or adjacent to the former landing. Eight photo points were established and will be used to document changes on the former landing in a qualitative manner (Figures 55-59).

Erosion control structures have worked well on this site. Planter boxes (Figure 60) at the base of the recontoured slope are log and board barriers keyed into steep, infertile soil. They provide a protected, stable planting substrate in harsh areas. All planter boxes remained secure and stable throughout the winter, and they trapped small particles of soil moving downslope.

Wattle bundles were buried in contour trenches, purposely constructed wider than the dimensions specified in the contract. Most terraces were about eighteen inches wide. They effectively provided a physical barrier to rilling and ravelling. Fine sediment and grass seed accumulated on most terraces.

Species most successful in sprouting in these wattle bundles were: willow (Salix sp.), thimbleberry (Rubus parviflorus) and salmonberry (Rubus spectabilis); species showing limited sprouting were: coyote brush (Baccharis pilularis var. consanguinea), salal (Gaultheria shallon), and Rhododendron macrophyllum. Stem cuttings of willow, coyote brush, thimbleberry, and salmonberry were also sprouting in June, 1979.

Figure 56: PP3 10/2/78
View towards C-Line landing prior to any rehabilitation work. Part of the landing failed, leaving much of the organic and inorganic debris perched precariously.

Figure 57: PP3 12/20/78
A dragline crane pulled back the unstable fill and debris, and a cat tractor moved it to stable skid roads. Wattle rows of willows and other species were planted on the slopes.

Figure 58: PP6 10/2/78
Before and after sequence showing the removal of the C-Line landing. The upper slopes have willow wattles; the steep lower slopes are protected by planter boxes.

Figure 59: PP6 12/20/78

Figure 60: 12/7/78
At the base of the C-Line landing (Site 78-5), below rows of wattles, planter boxes were secured to the slope. They were backfilled with soil and planted with willow stem cuttings to promote revegetation on an otherwise harsh site.

IV. EFFECTIVENESS OF EROSION CONTROL STRUCTURES

Several types and variations of erosion control structures were used after machinery work to stabilize slopes and gullies. The purpose of each structure and construction specifications are described in NPS Technical Specifications (U.S.D.I., N.P.S., 1978). This section will evaluate effectiveness of structures after the first winter and will discuss any problems.

Erosion control structures were constructed from materials available on or near the rehabilitation sites. Redwood slats were used in all wooden structures. Because of redwood's durability, properly placed wooden structures may last twenty years. In addition, correctly located rock structures are expected to endure at least that long, barring occurence of extraordinarily large storm events.

Erosion control structures alone will not provide a permanent solution to erosion problems. Structures are a temporary answer to immediate erosion problems. Vegetation must be firmly re-established on these sites to provide a long term decrease in sediment yield to stream systems. Adjacent to erosion control structures, several types of vegetation were planted to accelerate revegetation. Grass and brush seeding and fertilizing promote rapid, but short-term, ground cover on disturbed sites. Alder seeding, willow wattles and stem cuttings were planted to provide a protective canopy and a cohesive root mass in a few years. In addition, planting redwood and Douglas fir seedlings promotes establishment of a well stocked conifer forest which eventually mimics the original old-growth redwood forest.

A. Waterbars

Waterbars divert water off skid trails and roads and direct flow into its natural drainage. Effective waterbar construction includes locating the waterbar at a point along the road where runoff can successfully be diverted downhill to a less erodible slope, spacing waterbars frequently to prevent road gullies between waterbars, excavating waterbars into the ground surface so that runoff flows in a ditch, or gutter, rather than against a built-up berm that could wash out and placing adequate energy dissipation at the waterbar's outlet to prevent downcutting. Ideally, waterbars should endure until the road and waterbar are revegetated. Unfortunately, some skid trails were constructed through hillsides and formed deep, incised cuts. Rilling is a common problem on

these throughcut roads, and waterbars are not effective.

At Miller Creek, waterbars were excavated at least six inches into the road surface and built up six to twelve inches above the road surface. The sandy, pebbly soil in the berm loosened considerably after several freeze-thaw cycles, but the berms were massive enough to offset any weakening from decompaction. Trough gradients varies from 2 to 30%. Trough downcutting seemed to be a function of discharge rather than gradient. For example, a 10%-grade bar carrying comparatively large discharges downcut several inches, whereas a 20%-grade bar with less flow showed no signs of erosion. Where the gradient was less than 3%, water did not drain freely and some ponding and deposition occurred.

Energy dissipators composed of rocks larger than 2 1/2 inches in diameter (fist size) worked well to prevent erosion at waterbar outlets. In places, rocks promoted deposition of fines upslope of the dissipator. If an unprotected break in slope exists near the outlet of a waterbar, energy dissipation should extend beyond the break, even if it requires more than three feet (contract specifications) of rock.

Few problems were encountered. Of 46 waterbars built or repaired on Miller Creek, only three were rendered ineffective from winter flows. At one, the bar was breached where the berm was less than 12 inches high. At a second, ponding water in a 2% trough infiltrated through the bar, emerged downslope of the bar, and continued flowing in the gully. At a third waterbar, flow at an outlet cut back to the road where the berm was not extended beyond the outside edge of the road.

On Emerald Creek, five waterbars were repaired and eight more were hand-constructed according to the dimensions described above. Most waterbars received little flow, and only one problem was noted. A few inches of downcutting occurred on a steep waterbar where the ground was unprotected by rock or vegetation.

Waterbars on the Bond Creek Site were excavated by backhoe or hand-excavated. Fifteen waterbars were dug by backhoe on a main skid trail, at a cost of approximately $2 per waterbar. In contrast, 12 waterbars were hand-constructed at a cost of $30 per bar. An example of a hand-constructed waterbar on the Lower Bond Creek Unit is shown in Figure 61. Both types of waterbars effectively diverted winter runoff flows from skid trails onto vegetated areas.

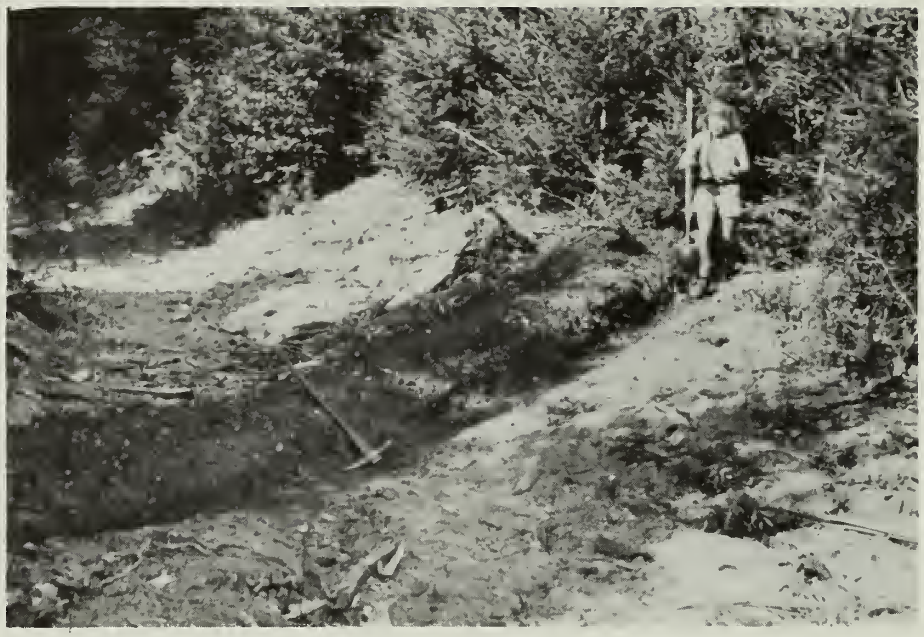


Figure 61: June, 1979
A hand-constructed waterbar on the Lower Bond Creek Unit. Runoff from the skid road is diverted into heavily vegetated area behind the person in the photo.

B. Planter Boxes

Planter boxes are redwood slats staked at least three inches deep into a steep rocky slope to inhibit ravelling on the slope and to protect downslope vegetation from rockfall. When keyed in adequately, these slats effectively trap loose soil and gravel. Unfortunately, substrate caught upslope of the slats is usually gravelly and is not conducive to revegetation efforts. When constructed, planter boxes can be backfilled with fertile soil to encourage vegetation upslope of the slats. Planter boxes may be staggered across a slope, but the entire width of the unstable slope should be protected at some point by the boxes. All planter boxes on the sites were made of redwood slats. Other physical barriers, such as logs and brush, may be staked into the slopes to achieve the same purpose at a lower cost.

On the Miller Creek, all but one of the one foot high planter boxes on a 65% slope were filled to capacity after the first winter. At one box, jute netting secured to the ground directly upslope of a box helped prevent sediment from completely filling the area above the box. Emerging groundwater undercut one slat, rendering it useless.

On the C-Line landing, all planter boxes remained effective and sturdy through the winter. Willow stem cuttings planted upslope of the boxes sprouted well in June, 1979.

C. Check Dams

Introduction

Check dams are wood, brush or rock dams built in small perennial or ephemeral stream channels or gullies. Check dams help prevent channel downcutting and help stabilize banks. Gullying and channel downcutting are substantial erosion problems on logged timberlands. Gullying on logged slopes occurs along logging skid roads, downstream from culvert outfalls, and on raw landslide surfaces. Downcutting can also occur in excavated stream channels where drainages have been cleared of road fill and organic debris during rehabilitation. Once a gully is initiated, it will enlarge for many years because infertile subsoil and oversteepened banks hamper natural revegetation.

Check dams installed sequentially in a channel prevent failure of individual dams by downcutting at the base of a dam (Figures 62 and 64). The lowest check dam in a gully reach should be constructed on a non-erodible base, and all upstream dams should be placed so that the sediment fill behind the downstream dam abuts the base of the next upstream dam. Therefore, check dams and their trapped sediment totally cover the channel reach, and running water moves over one check dam step, through the energy dissipator device, and onto the next lower level of ponded sediment.

Sediment deposited in the catch basins upstream of check dams also buttresses the toes of adjacent banks, and provides a substrate for vegetation. Channel bank and channel bed revegetation increases long term channel stability.

On the Miller Creek, twenty-four check dams were built to contract specifications (U.S.D.I., N.P.S., 1978) in two drainages (Figure 63). In general, check dams prevented downcutting. Even where the dams were filled to capacity with sediment, they are secure and still well keyed into adjacent banks. However, it was evident that several changes need to be made in the specifications to increase the efficiency of the dams.

A common problem in shallow, wide, and ill-defined channels is constructing a long enough check dam. Because it is often unfeasible to mill a single slab long enough to extend the width of the high water channel, wing walls were utilized. Wing walls are slats of wood staked at an angle in the catch basin upstream of the dam they direct flow towards the spillway and prevent water from cutting laterally around the check dam. To be effective, wing walls must overlap the sides of check dams at least six inches and must be at least equal to the height of the check dam.

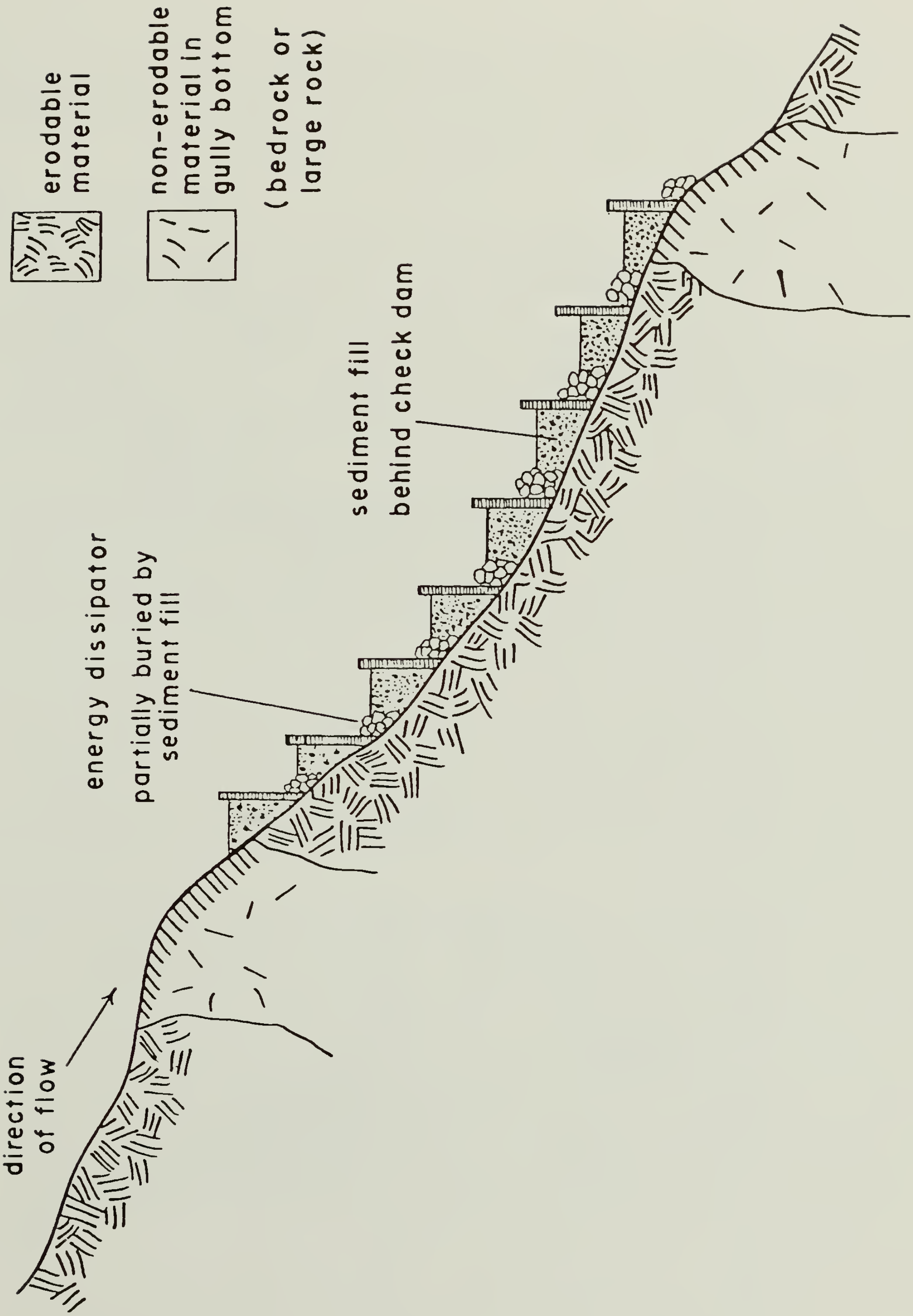


Figure 62: Profile along a gully bottom showing proper placement of a series of check dams with lowermost check dam built on a non-erodable base (called a base level).

Shallow spillways also cause lateral cutting. When freeboard height was less than five inches, lateral cutting occurred, even in narrow channels. Revised contract specifications require an eight inch minimum freeboard height.

Some dams are constructed with one board over another, (double slat dam), to provide adequate height to dams. If overlap between two slats is not watertight, seams must be caulked with moss, clay, or wood shims to prevent significant leaking. Sediment deposition occurred unevenly in dams with wide catch basins where water did not drain freely from the sides of the basin to the spillway. To correct this problem, during dam construction, edges of the backwater basin could be sloped down towards the center.

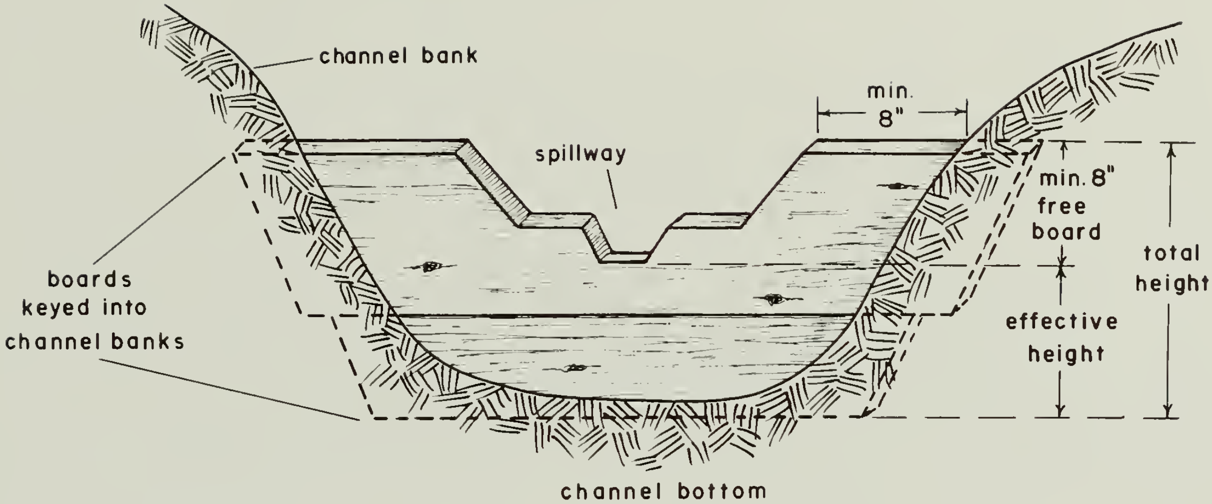
All dams at Miller Creek had rock energy dissipators (Figure 63) that generally worked well. In a few cases, as water flowed over the spillway and hit the rocks below, it was diverted sideways to the edges of the backwater basin. Here water potentially could pond or cut laterally around the dam if preventive measures are not taken (for example, wing walls).

On the Upper Bond Creek Unit, 128 check dams were installed in channels excavated by backhoe. Nearly all check dams are functioning as designed. At most former skid road crossings, the upper three to five check dams filled to capacity with coarse sediment. Sediment in catch basins above the check dams becomes progressively finer downstream.

Both rock and splashboards were used as energy dissipators below check dam spillways at Bond Creek. Rock (fist-sized and larger) worked well, and scouring was a problem only where rock did not adequately protect the channel below the check dam spillway. Rocking the channel for the entire width of the spillway, and extending the dissipator at least fifteen inches downstream of the base of the check dam prevented formation of a plunge pool below the check dam. The distance or width of energy dissipation below a check dam must be related to the height of the spillway and the potential stream discharge. That is, the greater the discharge and dam height, the farther the dissipation must extend down from the dam.

Where splashboards were used as an energy dissipator at Bond Creek, the check dam was built on top of the splash board so that no undercutting would occur below the spillway. This design worked well in most cases; however, in a few

Front View



Side View

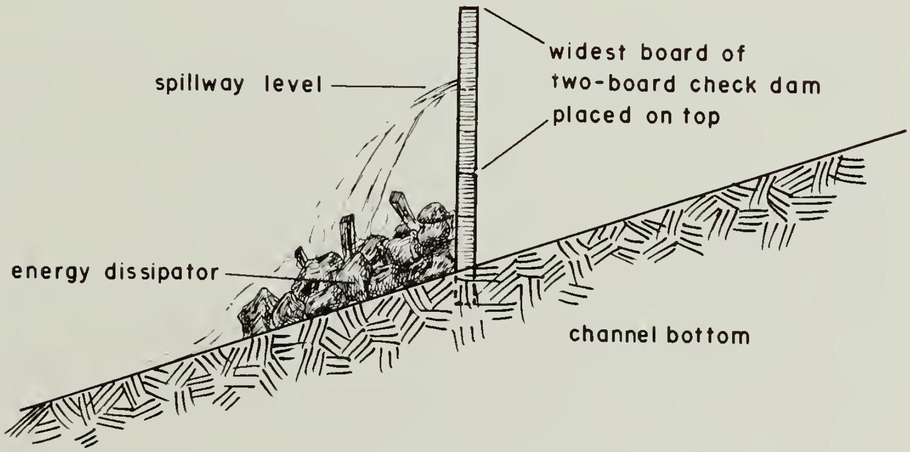


Figure 63: Schematic drawing of split redwood board check dam

instances leakage occurred between the splashboard and the base of the check dam (Figure 67). If fine material is used as backfill and packed well in the catch basin during dam construction this problem could be prevented.

At Bond Creek, downcutting is a common problem upstream of the highest check dams, indicating one of several things: the crossing should have been excavated deeper, check dams should have been installed farther upstream, or the channel should have been armored with rocks to prevent downcutting.

Several maintenance needs for check dams became evident after high winter flows. A CETA-funded group did the necessary repair work on Miller Creek check dams in early June, 1979, as part of their training program. Wing walls were installed above five check dams where lateral cutting threatened or had occurred. In backwater basins where poor drainage presented a problem, fill was sloped towards the spillway to promote free-flowing drainage.

Seepage occurred at Miller Creek in a few dams where water flowed through the fill upstream of the dam and emerged underneath the dam. Continued seepage would have undermined the dams. Seepage could have been prevented during construction if the bottom and sides of the dams had been packed with clean, fine fill (i.e., no organic debris or large gravel and rocks). The CETA crew removed the troublesome backfill and replaced it with fine-grained sediment to inhibit any further subsurface flow.

Banks along a check dammed reach are generally steep and somewhat unstable. Although willow wattles and stem cuttings were planted on banks more stem cuttings should be planted a year after check dam installation to take advantage of newly deposited sediment in catch basins. Cuttings should be especially dense along the edges of the channel at the toe of the banks. New vegetation adds support to banks and hinders later channel cutting. In Bond Creek roots from willow cuttings planted along the channel invaded check dam basins and added some binding to the fill material. Over a long period these roots will successfully stabilize the channel bed as wood check dams slowly decompose.

Most maintenance problems could have been avoided by careful adherence to contract specifications. Nevertheless, sufficient uncertainty exists at a site regarding the normal distribution and intensity of storms, the hydrologic mapping of a unit, and the effects of particular erosion control

structures in treating a problem that a winter maintenance crew is almost essential to preserve the effectiveness of erosion control efforts against unforeseen circumstances.

Brush check dams

At Miller Creek, small check dams made of Monterey pine boughs (an exotic species being eliminated from the park) were installed in rills on a through-cut skid road. The dams were six to eight inches high and held in place by stakes cut from tree trunks. In rills less than six inches deep, brush dams worked well, trapping fines and gravel. Brush dams were spaced four feet (slope distance) apart on a 55 percent slope, but they should have been spaced at half that distance. Gully downcutting may be reinitiated where brush check dams are spaced too far apart. Little experimentation has been done in the park with brush check dams, but initial results indicate that further work with this medium is warranted.

Figure 64: June, 1979
A series of check dams protect a stream channel cleared of road fill and organic debris on the Bond Creek Unit. All dams are well keyed into channel banks and bed. Dams are located so that sediment deposited behind one dam abuts against the base of the next upper check dam. In this manner, the entire disturbed reach of channel is protected from downcutting.

Figure 65:
A close-up view of a series of check dams in the Bond Creek Unit. Summer flow is draining through low-flow spillways. Catch basins upstream of the check dams are filled with sediment deposited during winter high flows. Both rocks and splashboards are used as energy dissipators. Note willow stem cuttings are sprouting and locally, grass is well established.

Figure 66: January, 1979
Miller Creek Unit check dams convey winter flows through broad, high-flow spillways. Large rocks are used as energy dissipators below spillways. Note willow stem cuttings on both channel banks.

Figure 67: June, 1979
Leakage between splashboard energy dissipator and base of check dam. Ponding effect of the check dam is lost and consequently little sediment is deposited in the catch basin upstream of the dam.

Figure 68: September, 1979
Same series of check dams as figure 66 showing revegetation after one season. Willow (salix, spp.) have sprouted from stem cuttings while horsetail (Equisetum, spp.) invaded naturally.

D. Water ladders

Water ladders convey water across a steep channel reach while protecting the channel from downcutting. On 1978 sites, they were used in conjunction with check dams or at the downstream end of cross road drains. Water ladders are useful where check dam installation is difficult to excavate. If all flow can be directed over the ladder, they can also be used to protect a knickpoint or headcut in a gully from migrating upstream.

Water ladders must be designed to accommodate fairly large flow events (at least a 10-year storm). Since water discharge data is rarely available for sites where water ladders are required, other factors (original channel size, drainage area, soil, ground cover, and storm potential for the area) must be considered. Water ladder dimensions should generally be the same as the width and depth of the stream channel above or directly below the water ladder site.

Three designs of water ladders were used on the Miller Creek unit (see sketches). Type 1 was built of hand-split and hand-sawed redwood slabs. Because of the hand-split wood had an uneven surface, ladder treads were not flush with side pieces, and water seeped through these cracks to flow below the ladder. In addition, ladder treads were not level and water flowed towards the side of the ladder, accentuating leakage problems. Although the knickpoint under the top of the ladder was still protected, undercutting of the ladder would continue and eventually undermine the structure unless leakage problems were corrected. Solutions to the leakage problem include, nailing short slats of wood over and under the treads parallel and flush with the side pieces, caulking all cracks, or cutting grooves on top of the treads to direct low flow towards the center of the ladder. In June, 1979, a CETA work crew repaired the water ladder to prevent further leakage. Figure 69 shows a Type 1 water ladder before repairs were made.

Type 2 water ladder (Figure 70) at Miller Creek is fully functional, and is also built from hand-split redwood. Wing walls above the ladder effectively directed flow over the ladder. The ladder is built in two overlapping sections, conforming to the channel configuration and in-channel debris. The ladder's top tread is keyed into

Type I - Water Ladder

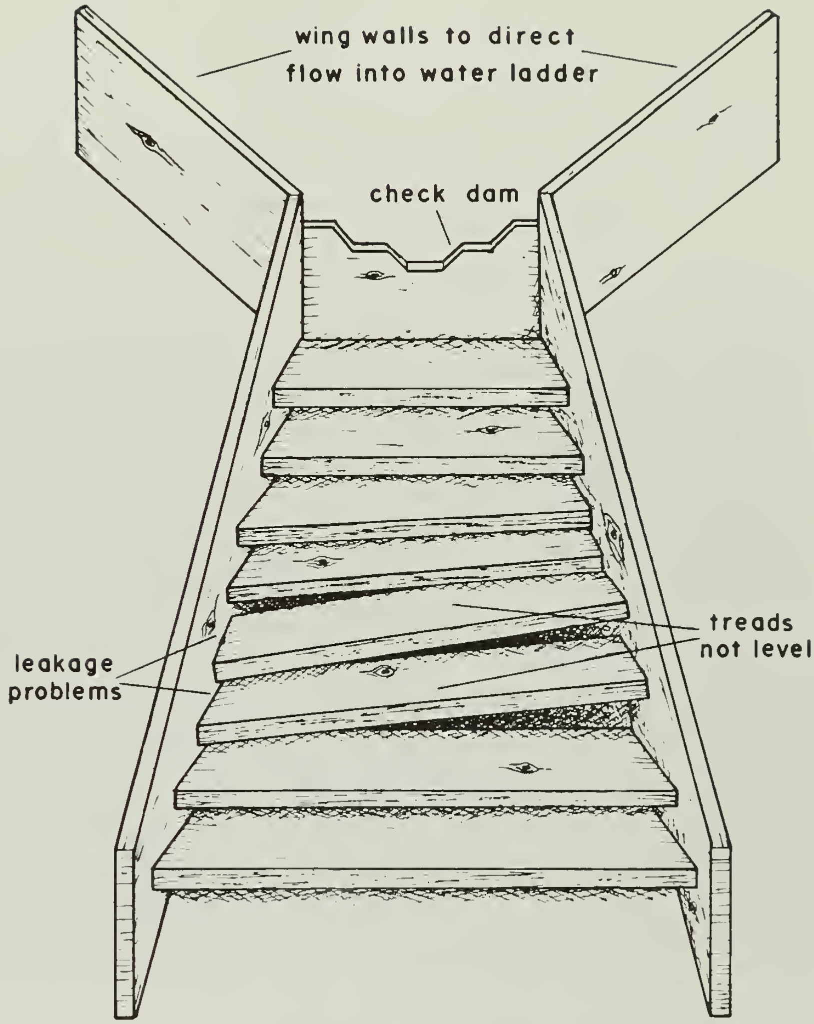


Figure 69:

Type 1 Water Ladder

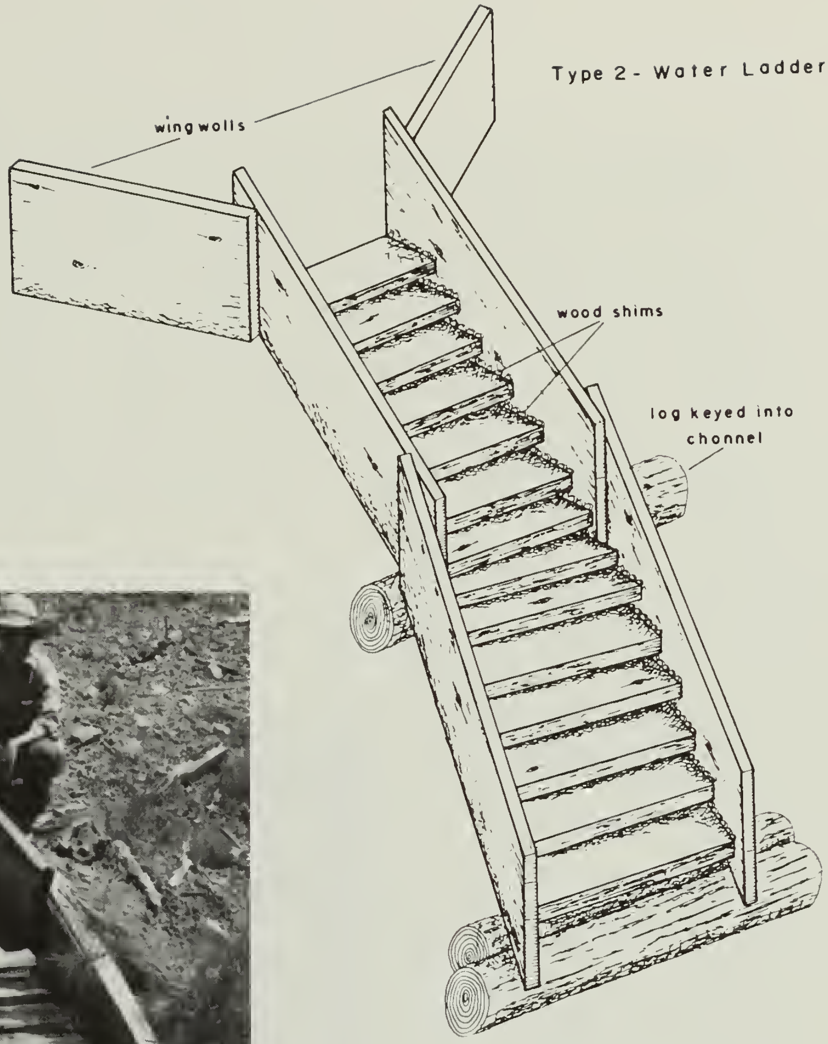


Figure 70: Type 2 Water Ladder

a partially buried log. Some scour (4 inches deep) occurred upstream of the log, but rocks were deposited in the scour hole. There is little danger of the entire log being undercut. The ladder was large enough for 1978-1979 winter flows; however, a large storm event would probably overtop the structure. Dry wood shims were hammered into all cracks. The shims swelled upon wetting and sealed the seams of the ladder, preventing almost all leakage. The energy dissipator at the foot of the ladder is composed of large logs in the channel (some were already keyed into the channel before the ladder was built). No downcutting occurred below the ladder.

Type 3 (Figure 71) was a water flume constructed at Miller Creek from milled redwood slabs. A check dam built at the top of the water flume directed water through its spillway into the flume. A layer of large rocks was used to line the channel bed, and the flume (three 7-foot sections) was installed on top of the rocks. Braces built across the top of the flume add support to the structure.

The Type 3 design developed several problems. Cracks between two slats of the check dam leaked water to the channel outside the flume. The flume's area (18x18 inches) is too small to handle high flows. The rocks under the flume settled and as a result, the flume shifted slightly. The three sections did not overlap adequately, and some leakage occurred. Some baffles or deflection boards in the flume caused water to jump over the sides at high flows. The flume's outlet did not face downstream, but was slightly directed towards the left bank. An energy dissipator of large rocks placed in and around a trash rack was not sufficient to prevent bank erosion below the flume.

To summarize, the most significant problem by far with Type 3 water flume was the small cross-sectional area of the flume that will not accommodate runoff generated by even a 10-year storm event. The flume will probably wash out, creating severe erosion at the break-in-slope and leading to the development of a gully headcut.

At Emerald Creek, four of five water ladders were Type 4 design (Figure 72). The fifth was a one-section waterflume.

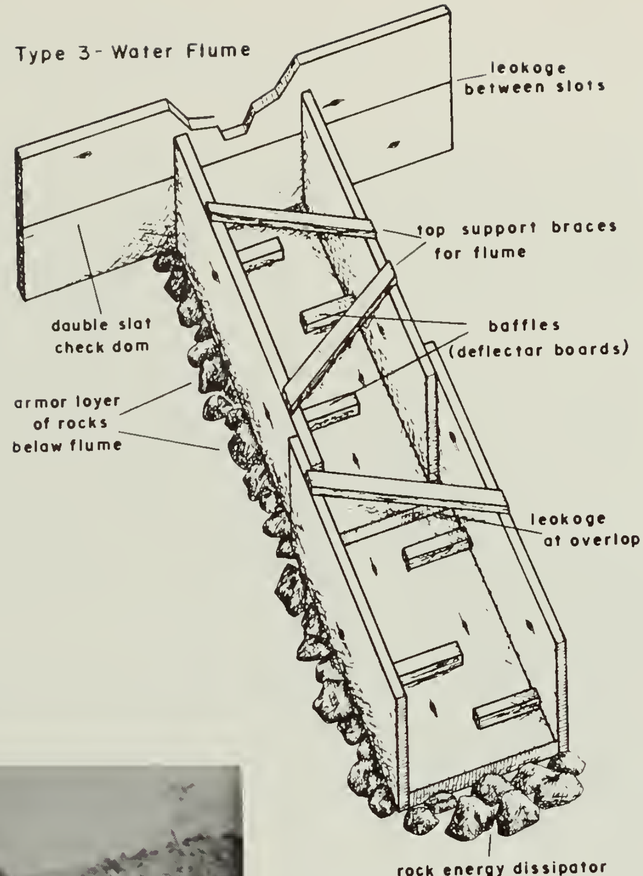


Figure 71: Type 3 Water Flume

All five were constructed at the downstream end of major crossroad drains. Wood for the ladders and flume was milled with an Alaskan Mill. Grooves (about 1/2 inch deep) were cut into the top side of the Type 4 ladder treads to direct flow towards the center of the ladder.

At lowflow, Type 4 and other ladder types allow drops of water to go over the edge of the tread, cling to the bottom of the tread while moving upstream slightly, and finally drip down (Figure 73 - top tread). If tread overlap is not sufficient, the drops fall on unprotected soil and flow under the ladder. Slats of wood nailed under the treads prevent leakage from this source; cutting the downstream edge of the tread at an angle may also help (Figure 73).

Short slats nailed below treads parallel and adjacent to side pieces on Type 4 ladders seem to prevent side leakage (Figure 74) except when the slats extend beyond the downstream edge of the tread. In those cases, water flowed over the treads onto the slats and leaked between the slats and the side piece of the ladder.

The water ladder entrance must be free of obstructions. Even a two inch high board at the top of one ladder caused ponding and leakage problems. It is essential for the water ladder inlet to direct all runoff onto the ladder, allowing water to drain freely.

At Emerald Creek, ladder treads were level and dipped slightly downslope. Ladders were keyed in well to the channel, and conformed to channel (in this case, a crossroad drain) dimensions. No downcutting occurred where channels are protected by these water ladders.

A water flume was built at Emerald Creek in a design similar to Type 3 water ladder (described below). Baffles within the flume were raised slightly above the floor of the flume so that at low discharges water flowed unimpeded down the flume and no sediment accumulated behind the baffles. At high flow, however, the baffles effectively checked flow through the flume. This flume is watertight with no leakage problems and is set firmly into the channel bed (in contrast to the Miller Creek flume constructed on a layer of rock).

The flume enters a wide water ladder, which in turn discharges flow onto an energy dissipator. Wing walls were installed

Type 4 - Water Ladder

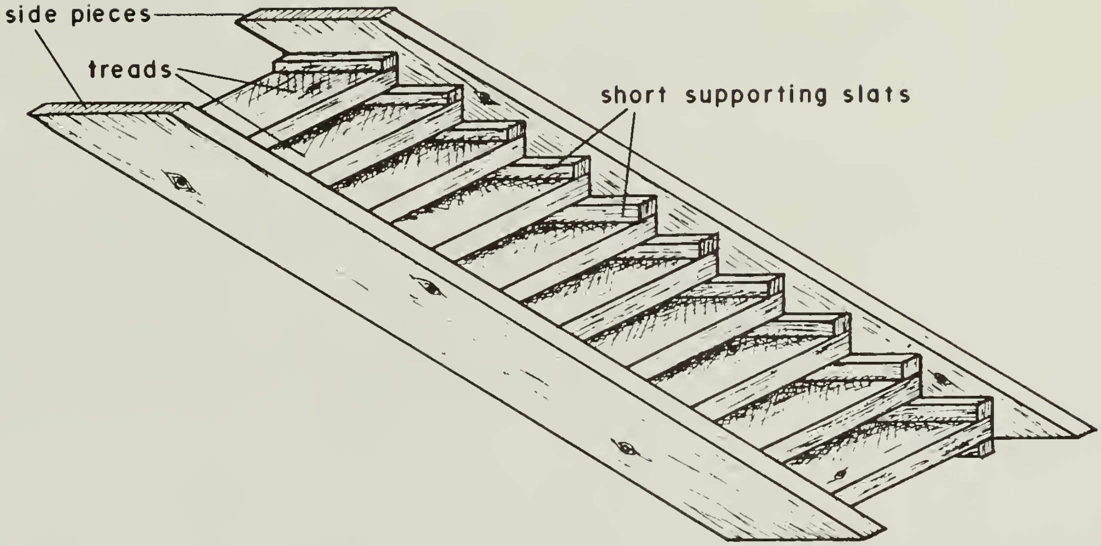


Figure 72: Type 4 Water Ladder

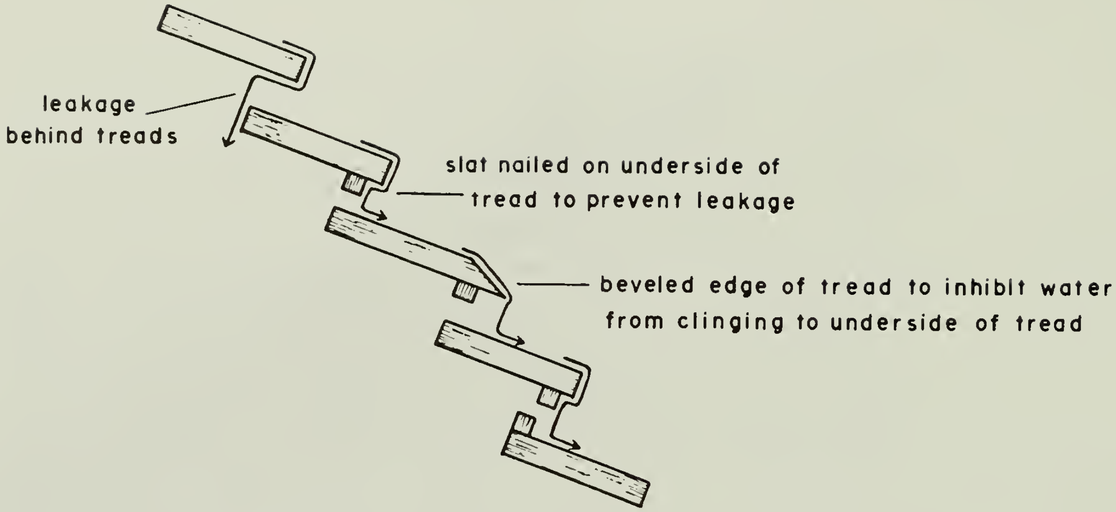


Figure 73: Side view of water ladder treads

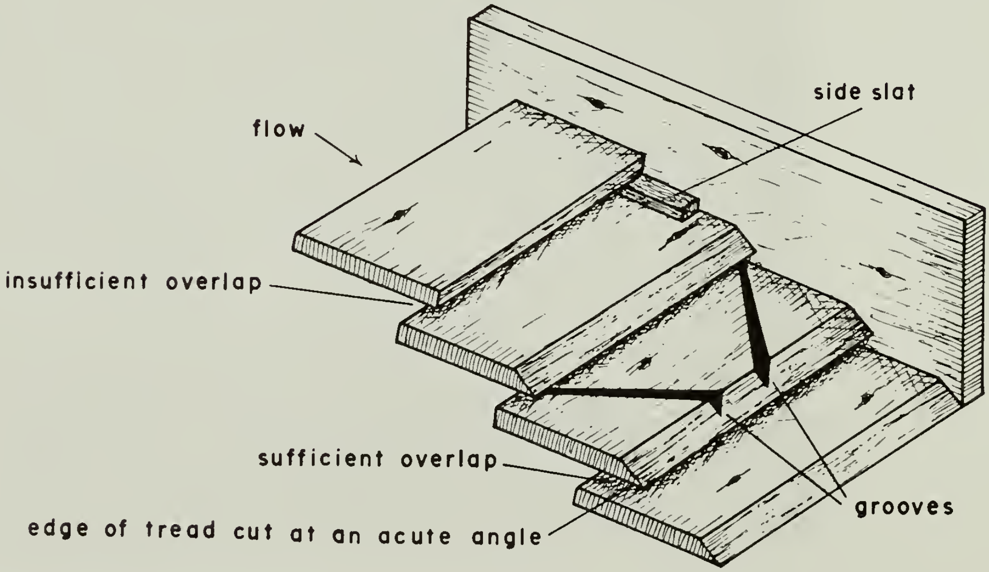


Figure 74: Oblique view of water ladder treads

at the junction of the flume and the ladder to direct any flow that may have leaked out of the flume onto the ladder. The overlap between flume and ladder is adequate, and this structure has no apparent problems.

In general, water ladders on the Emerald Creek site functioned better and are sturdier than those at the Miller Creek site. Use of milled boards (from an Alaskan Mill) in their construction is probably the major reason for their superior quality. Adequate energy dissipation below water ladders is also critical to ladder success as is correct engineering of the water ladder entrance point. Where water ladders remained watertight throughout the winter, they prevented upstream migration of knickpoints in channels.

E. Gully plug

Stopping continued erosion of an upper end of a gully (headcut retreat) is a major goal in gully control because a headcut is a critical point of growth in an active gully. Gully plugs are devices that armor a headcut and prevent upslope migration of a gully. In addition, the gully reach below the plug must be stabilized by vegetation and/or check dams to prevent the gully plug from being undermined and failing.

By September, 1978, a long gully had developed on the Bond Creek Unit (Figure 48), and a six foot knickpoint in the gully was beginning to migrate upslope. A gully plug installed at the knickpoint protected the headcut from further migration and erosion while conveying water across the sensitive area (Figure 75). In this respect the gully plug was used as an alternative to a water ladder in treating this erosional problem.

The gully plug was constructed by clearing all debris from the gully below the headcut. Re-bar was driven into the gully bottom and a layer of hand-placed rock overlain by organic debris was wedged in and around the re-bar to cover the gully bottom. This armoring was capped by a double layer of chicken wire (1/2 inch mesh), secured into the hillslope with diagonally and vertically driven re-bar.

Three submerged spillways (that is, spillways flush with the channel bed) installed in the gully directly above the headcut prevented downcutting above the erosion control device. Below the lowest submerged spillway a horizontally placed, slightly outsloped splashboard was keyed into the head of the gully, directing runoff away from the gully head scarp and onto the gully plug itself. The splashboard was supported and secured by rebar. A layer of rock and chicken wire was placed over the splashboard, extending from the base of the lowest submerged spillway to the rock and debris layers below the gully headcut.

Gully walls and the area around the submerged spillway were planted with willow stem cuttings and with transplants of _Whipplea modesta_. Prior to this planting there was little vegetative cover on this site.

Figure 75: January, 1979
The gully plug on the Bond Creek Unit has collected a considerable amount of gravel and fine-grained material while protecting the headcut of the gully from migrating upstream. Three check dams with submerged spillways are located directly upstream of the gully plug (by the person in the photo) to prevent downcutting above the gully plug.

The gully carried heavy flows in winter and much sediment was transported to the gully plug. Fine particles ranging up to small gravel filtered through the chicken wire and were deposited in the debris below. Cobbles and large gravel were deposited and temporarily stored on the chicken wire or at the base of the gully. The gully plug was not designed to trap all sediment and some gravel will continue to be delivered to the stream channel below the gully plug.

The gully plug effectively prevented the upward migration of the gully headcut. The channel directly above and below the headcut was adequately protected from erosion and no downcutting occurred around the erosion control structure. The structure remained keyed in securely after winter flows. Vegetation is beginning to grow adjacent to the gully and will eventually help stabilize gully banks.

The gully plug cost $770 to construct; the construction of an equivalent water ladder on this site would have cost approximately $700. The effectiveness of the two devices is similar. A gully plug seems to work better at sites with ill-defined channels and an abundance of rocky debris.

F. Energy dissipators

Wherever an erosion control structure discharges water, some device is needed to dissipate the energy of flowing water to protect the slope or channel below. The dissipator may be made of rock, slash, or brush. The size and extent of the dissipator depends on the amount of flow an erosion control structure discharges. For example, a low-flow waterbar would not require an energy dissipator nearly as large or as well-keyed in as a high-flow water ladder.

Several types of energy dissipators were used below water ladders, water flumes, and cross road drains (those used in conjunction with waterbars and checkdams were discussed previously). Each energy dissipator should break up the force of flowing water, convey flow across a slope or channel reach while preventing erosion, and protect the upstream erosion control structure from undercutting.

On Miller Creek, the energy dissipator for Type 1 water ladder was a pile of brush, logs and rocks six to twelve inches deep spread four feet down the channel. Because a natural "bench" (with a 20% grade) was at the foot of the water ladder and water flow was not very strong, the logs were not staked into the ground. Little movement occurred during the winter.

Type 2 water ladder was built to discharge onto a small log jam that was already well keyed into channel bottom and banks. Large logs show no sign of movement and work well in dissipating the energy of the water. No problems with scour or undercutting are seen.

At the foot of the water flume (Type 3), a wood box was staked into the channel and filled with large rocks. At high flows, water overtopped the trash rack and eroded the left bank. For this steep (65%), perennial stream channel, more extensive energy dissipation is needed to protect the channel, banks, and water flume.

On Emerald Creek, several types of energy dissipators were constructed below water ladders and at the outlet of cross-road drains. At the foot of the water flume/ladder combination, a grizzly energy dissipator consisting of slats of wood running from the edge of the water ladder to the channel bed was installed parallel to the stream channel. A layer of large rocks was placed under the wood slats.

Figure 76. The 'grizzly' energy dissipator below a water ladder. Large rocks were placed under the slats of wood as well.

Water from the ladder drips down the slats or trickles through to the rocks below. No signs of undercutting are visible (Figure 76).

Another form of energy dissipation is a herringbone pattern of redwood slats staked into the ground and backfilled with rocks. Some slats were undercut by winter flows; others worked well. Success of the slats seems to depend on the pattern in which they are set (Figure 77). Alternating slats must overlap four to six inches and be fairly close together in order to effectively handle flows and minimize downcutting (Figure 78). Rocks upstream of the redwood slats protect slats from the scouring action of unimpeded flow. Even with sufficient overlap herring bone dissipators do not prevent downcutting in the channel. They should not be used in place of a water ladder or check dams to prevent erosion in an area where downcutting is expected.

Successive piles of rock held in place by redwood stakes in the channel is another type of energy dissipator (Figure 79). This dissipator did not receive much flow, so its efficiency was not rigorously tested. Nevertheless, the dissipator did handle low-to-intermediate flows well, and no signs of undercutting are evident. More testing of all types of dissipators under high flow conditions is necessary.

By far the most effective energy dissipation is dense, compact concentrations of logging slash such as is left at the outer edge of landings during yarding operations. Unfortunately, it appears that hand placement of slash at the downslope end of cross road drains was not effective because runoff tends to flow under the slash rather than through and over it. On Emerald Creek, token placement of slash as a dissipating measure was a waste of time. If slash is to be employed effectively, it must be cut up to fit channel dimensions, be secured in place and be of sufficient concentrations to interrupt the flow of water.

Willow wattle bundles installed parallel to the stream channel below a cross road drain were also tested. The wattles that are still alive in June, 1979 will probably not survive the summer because they have become too exposed by channel erosion. Perhaps the effectiveness could be increased by using wattles in conjunction with other channel stabilization structures.

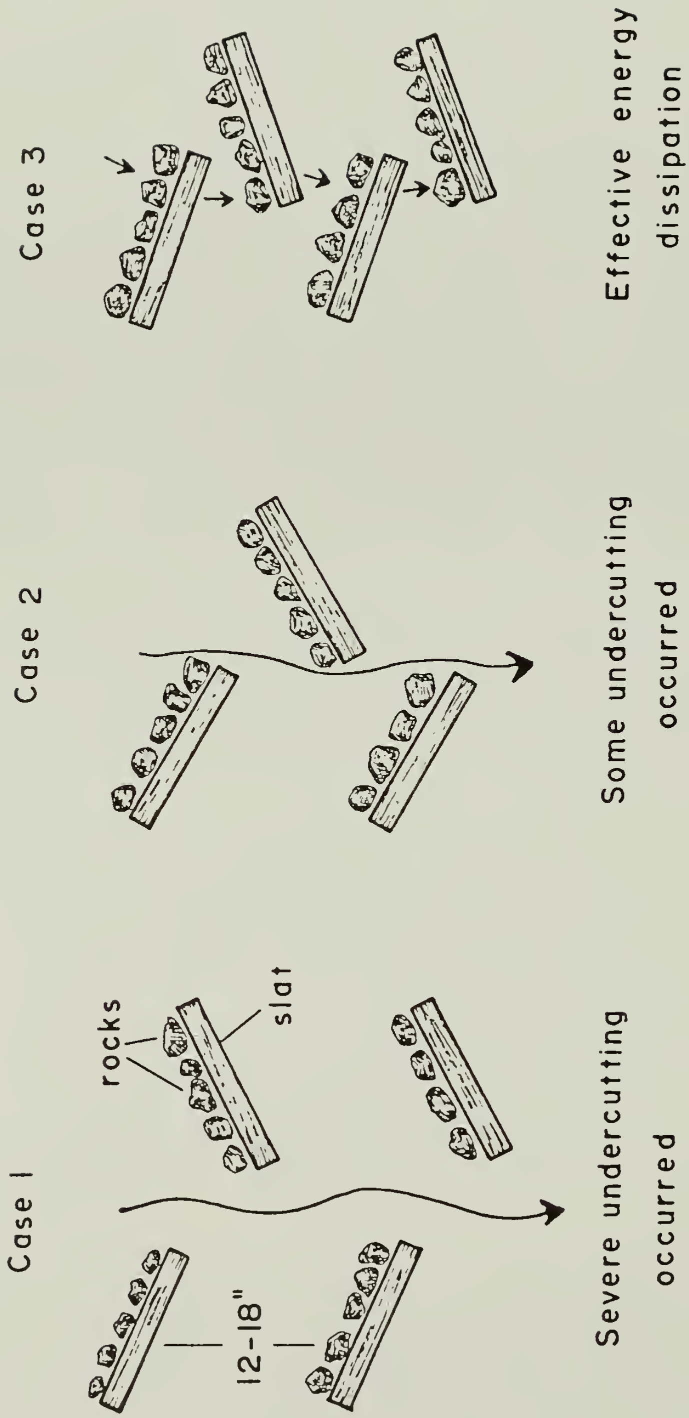


Figure 77: Design of herringbone energy dissipators.

Figure 78: Emerald Creek Herringbone energy dissipator below cross road drain has been undercut. In this case, the distance between boards was too large, and the upstream sides of the slats were not protected by rocks.

Figure 79: Emerald Creek CRD 15
Piles of rock anchored to the slope below a cross road drain, filter runoff through them and dissipate erosive energy.

G. Crossroad Drains

Crossroad drains are used to carry water across outsloped roads. In effect, they are short man-made stream channels. Crossroad drains were used primarily at the Emerald Creek Unit and most of the following discussion is based on results from that unit.

The proper location and frequency of crossroad drains is critical to insure a minimal amount of surface erosion and maximum possible slope stability for the recently outsloped roadbed. At Emerald Creek, crossroad drains were placed where culverts formerly carried runoff across the road alignment, where surface runoff channels entered from upslope, where excessively wet areas were evident by the presence of Equisetum sp and Juncus sp, or by persistent seepage during the dry season, and where cutbanks and/or slopes above the cutbank were unstable and actively failing through slumping or slump/earthflow. To ensure the best possible placement of crossroad drains, areas of surface runoff, seepage, and slumps should be flagged along a road section during the winter season prior to road rehabilitation.

During construction of crossroad drains, a catchment area should be excavated at the drain's upslope end to collect runoff or emerging groundwater. Side slopes should not be excessively steep (see below), and where possible, the downslope end of the drain should feed into a pre-existing drainage course so that runoff will not erode a new channel in the slope. In many cases, a crossroad drain must discharge onto an uneroded slope and adequate energy dissipation is essential.

At the heads of a few crossroad drains, cutbank failure occurred because wet hillslope material was inherently unstable. Slumping was expected in these areas and the crossroad drains were constructed wide enough (6-10 feet) to accommodate small failures and still effectively drain water. For the most part, dimensions of the crossroad drains were adequate. Banks need to be pulled back to a gradient less than the angle of repose for the excavated material (less than 55%). For example, at Emerald Creek, crossroad drain 16 was a former culvert location and a small portion on the right bank failed because it was too steep. Channel gradient of crossroad drains should be between 5 and 20 percent, depending on the slope of adjacent hillsides. Ponding water results from a too

gradual drain whreas a steep drain promotes channel erosion and downcutting.

At the downslope end of most crossroad drains the remaining road bed fill dropped steeply to the natural slope below, creating an abrupt break-in-slope. In anticipation of downcutting problems at this break-in-slope, various energy dissipation devices (see above) were installed. Despite these preventive measures, downcutting at the downslope end of crossroad drains is occurring and this downcutting is starting to migrate up the crossroad drain troughs and undermine rock armor. This downcutting has not progressed significantly after one winter season, but in future winters many crossroad drains will be undermined by this process. In retrospect, check dams started on the natural slope and built progressively upslope to the level of the crossroad drains may have prevented downcutting of those corssroad drains where a natural channel already existed below the drain. The problem is more difficult to treat where crossroad drains discharge onto slopes without pre-existing drainage channels.

Since crossroad drains are newly constructed channels carrying water for the first time, they are completely unprotected from high flows. When the catchment area of the drain is large, or when the gradient of the drain is steep, downcutting and channel enlargement may occur from winter flows if no protection is provided.

On Emerald Creek, manually placing large rocks (greater than four inches in diameter) in the crossroad drain channels protected the drains from downcutting. Because the lower three-quarters of the former C-90 Road had been rocked, a plentiful supply of suitable rocks was available. Over the winter, fine sediment settled in between the rocks, tightly packing them together, and armoring the channel bed (Figures 80 and 81).

It is important to completely cover the channel bed with rocks, and rocks must abut directly against the banks. Where the toe of the banks or the bed was exposed, lateral erosion and downcutting occurred during winter. Once a new channel starts eroding the toe of banks adjacent to the protective layer of rocks, the rocked channel bed is abandoned and rendered useless. In addition, adequate energy dissipation is needed at the outlet of the crossroad drains because downcutting below the drain can migrate upstream and undermine the rocked channel lining.

Drains built on the unrocked portion of the C-90 Road (at the upper end of the unit) were not rocked because of the lack of suitable material. These drains received little flow and have gentle gradients (less than 20%). No downcutting problems occurred. Grasses and cattails are lush along the crossroad drains, and their root masses help stabilize the drains.

Figure 80: Manually-placed coarse rock on the bed of a cross road drain prevents downcutting of the channel bed while allowing unhindered flow of runoff through the drain.

Figure 81: A thick stand of grass in a moist cross road drain adds support to the banks by its dense root mass. The grass and rocks trap fine soil particles that would otherwise be washed downstream.

H. Willow wattles

Wattles are bundles of flexible twigs and branches of at least some sprouting, native species tied together. Wattling is the process of placing wattles in contour trenches on slopes, staking the wattles in place, and then covering the wattles almost completely with soil. Once in place, wattles retard surface erosion and revegetate bare slopes through the sprouting of branches in the bundles.

Wattle effectiveness in inhibiting erosion on disturbed slopes seemed to vary with the individual rehabilitation sites, and the success of wattles was previously discussed in the evaluation of the respective sites. In addition, some general statements can be made that were applicable to all sites.

Wattles sprouted vigorously on moist, steep sites in fine-grained material. This is fortunate because these slopes are most susceptible to surficial erosion and slumping, and they need the protection of vegetated terraces. Wattle burial was also an important factor. Highest survival occurred in wattle bundles that were ninety to one hundred percent covered with soil and in which air spaces in wattle bundles were partially filled with soil.

Wattles did not work well on dry, rocky slopes. On these sites, dry ravel is the major surficial erosion process, and physical barriers should be used to restrain downslope movement of material. From a time and cost perspective, wattles are not an efficient mode of erosion control on biologically harsh sites. Alternatives which depend less on revegetation for success should be utilized in the future. Nevertheless, on pulled stream crossings and similar sites, wattles are effective in stabilizing disturbed banks.

I. Mulches

Mulches may help keep soil in place on recently disturbed slopes. They form a permeable mat that can dissipate the impact of raindrops and impede rilling on the soil surface. Loose mulches (straw, wood chips, leaves, branches and bark) work well on flat, protected areas. Where mulching is desirable on steeper slopes (greater than 10%) or where wind exposure is a problem, an interwoven biodegradable fabric that can be staked in place can be used. Before mulch is applied, slopes should be seeded to establish vegetation on treated areas.

Three types of mulches were used on portions of the outsloped road in Upper Miller Creek, redwood chips, straw, and jute netting (see Figures 82, 83, 84). Mulched slopes (7700 square feet in all) were composed of the same soil material and had similar gradients (20 to 30%). Mulches were spread by hand, and cuttings of willow and other species were planted through the mulch to secure it to the slope.

The effect of mulches on soil properties (texture, pH, nutrient levels, etc.) is not yet known, but will be tested more extensively in the future. Comparison data of seedling and stem cutting survival on straw-mulched versus control slopes are not yet available. Trace amounts of wild wheat (Avena sativa) found on the straw-mulched sites were probably introduced with the straw.

In general, mulches have shifted slightly downslope over the winter, but little movement of large soil particles has occurred. In June the ground under the mulches (especially the redwood chip mulch) was moist, while on the control sites the soil was dry. Mulches prevented some rockfall from upslope from continuing downslope onto wattled areas. Mulches (especially the straw) also intercepted and dispersed rills originating upslope.

Jute netting without an under-layer of mulch was used on a steeper, rockier slope. The planter box directly below the jute netting was the only one on that slope that did not fill with dry ravel and rockfall over the winter months. Thus, jute netting seems to inhibit the downslope movement of soil particles which would otherwise be susceptible to dry ravel.

Figure 82: Redwood chip and brush mulch was spread on the outsloped road and Miller Creek, and was then covered with jute netting.

Figure 83: A close-up view at Miller Creek of the jute netting showing the stem cuttings which were used to secure the netting to the slope.

Figure 84: A close-up view of straw mulch and stem cuttings at Miller Creek Unit.

V. EVALUATION OF 1978 WORK METHODS

Equipment rental agreements were used to obtain heavy equipment for major earthmoving tasks. Fixed-price service contracts were written and let to manual labor work crews to build erosion control structures on rehabilitation sites. Advantages and shortcomings of these methods are discussed below.

A. Heavy equipment rental agreements

In performing 1978 rehabilitation work, Redwood National Park entered into equipment rental agreements with local firms to rent their equipment and operators on an hourly basis. Because the amount of heavy equipment work was relatively small, this procedure offered several advantages to the Government over contracting. Problems treated by heavy equipment are unconventional, and site specific solutions must be formulated for them. Conditions in the field may change as excavation proceeds. A contract for heavy equipment use would require unusually detailed specifications, and yet would have to allow a great deal of flexibility to accommodate changing project needs. The administrative work involved in such a contract would be much greater than that involved with a purchase order for equipment rental. However, in future, larger, projects, an indefinite delivery contract (CFR #41, 1978) may be used.

In addition, some types of heavy equipment contracts require performance bonding to assure a quality job. Few bidders would want to risk bonding on these previously untested techniques, and the contract bids would increase in price accordingly. Through equipment rental, the Government accepts responsibility for the success of the project, and in turn, can direct the equipment to exactly fulfill project needs.

B. Manual labor contracts

Rehabilitation of logged timberlands is a new field, and methods used in erosion control efforts are often unconventional or not well tested. It is to the Government's advantage to encourage innovation and creativity on the part of the contractor in supplying erosion control services. Flexibility in contracts is desirable. At the same time, high quality standards must be maintained and the objectives of the watershed rehabilitation program met. Many erosional problems must be treated on a site-specific basis, and do not lend themselves to description under broad, generic contract specifications. The design of a contract must reflect the needs of the specific rehabilitation project.

Several types of contracts exist (CFR #41, 1978), and there are advantages and disadvantages involved with each (Federal Procurement Regulation, #41, 1979). The contract chosen should promote the Government's best interests. Contracts vary in the degree of responsibility assumed by the contractor for the cost of performance. For example, under the formally advertised, firm fixed price contract, the parties agree that the contractor assumes full responsibility, in the form of profits or losses, for all costs under or over the firm fixed price. In contrast, under the cost-plus-a-fixed-fee contract, profit rather than price, is fixed and the contractor's cost responsibility is minimal.

Contracts for the three major 1978 rehabilitation units (78-1, 78-2, and 78-3) were formally advertised firm fixed price contracts. In this type of contract, the contractor has a maximum profit incentive for effective cost control and contract performance. The advantage of this type of contract is that it imposes a minimum administrative burden on the contracting parties. A certain amount of flexibility can be written into these contracts. For example, a maintenance clause can be included to require the contractor to return to the unit during or after winter flows and perform any maintenance needed on the erosion control structures. A percentage of the total contract price would be withheld until the maintenance was completed.

Flexibility is possible through another contract device, the bilateral modification. If a change in the contract is required after the contract is let due to some unforeseen circumstance, both parties may agree, in writing, to a change, and the purpose of the contract will still be achieved.

The 1978 contracts were considered service contracts, and performance bonds were not required of the contractors. In lieu of performance bonds, contract retention was used to assure a satisfactory and completed job. For each pay period, ten percent of the invoice was held back until the contract was successfully completed.

Several problems arose in using a firm fixed price contract, most of which could be avoided easily in the future. Because of time constraints, manual labor contracts were written before heavy equipment work was completed on the rehabilitation sites. Therefore, a contractor was bidding on a job that was only an estimate of what the true job would be.

In a firm fixed price contract, definite design and performance specifications are essential. In the 1978 contracts, several ambiguities in contract specifications surfaced during the term of the contract which will be corrected in future contracts. First, contractors were asked to bid on linear feet of willow wattles. Contractors were given the approximate area to be wattled (in square feet), but no formula was provided for computing the amount of linear feet of wattles required. Second, contractors were asked to bid on a price per check dam. Check dams may vary in height and width, and specific dimensions of gullies were lacking in the contracts. In addition, the number of check dams necessary to protect a channel reach depends on check dam height. A contractor may choose to build numerous short dams rather than a few taller dams. Thus, it may be better to ask a contractor to bid on checkdamming a gully of a specific length, width, and gradient instead of bidding on individual check dams. Third, the length of waterbars varied greatly from site to site; yet the contractor was asked to bid on an 'average' waterbar. Different tasks should be categorized and bid on as separate units.

Because the rehabilitation sites are erosionally sensitive, it is advantageous to have only one contract group working per site to minimize impact on the site. This is one reason why the 1978 contract bids were chosen on the basis of the total price bid, even though unit prices were required on the bid schedule. These contracts also specified a sequence of tasks to be done, assuring that priority erosion control structures were done first. Time of delivery was specified in these contracts; some tasks are weather-dependent and a clause for flexibility in timing should be included in future contracts.

Rehabilitation Sites 78-4 (Lower Bond) and 78-5 (C-Line landing) were done under the system of 'Requests for Quotations' rather than under actual contracts because of the amount of work required was relatively minor. Specifications for erosion control structures were identical to the contract specifications. The advantage of the request for quotations is the minimum amount of time and of administrative processing necessary to initiate work on the site.

REFERENCES

Alexander, E. et al, 1959-62, Humboldt County soil vegetation survey, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station; 16 maps, scale 1:31.680.

Geological Society of America, 1979, A fieldtrip to observe natural and management-related erosion in the Franciscan terrain of Northern California; Geological Society of America, Fieldguide for Cordilleran Section meeting field trip on April 12-14, 1979, 247 p.

Harden, D. et al., 1978, Mass movement in the drainage basin of Redwood Creek, Humboldt County, California - a Progress Report. USGS Open File Report. 78-486, 161 p.

Iwatsubo, R.T. et al, 1976, Redwood National Park studies data release Number 2, Redwood Creek, Humboldt County, U.S. Geological Survey Open File Report 76-678, 247 p.

Janda, R.J., 1975, Watershed conditions in the drainage basin of Redwood Creek, Humboldt County, California as of 1973; U.S. Geological Survey Open File Report 75-568, 267 p.

Janda, R.J., 1978, Summary of watershed conditions in the vicinity of Redwood National Park, California, U.S. Geological Survey Open File Report 78-25, 82 p.

Nolan, K.M., Dr. Harden, and R.J. Janda, 1976, Graphic and tabular summaries of recent changes in stream cross-sections for Redwood Creek and selected tributaries, Humboldt County, California, U.S. Geological Survey File Report 76-396, 24 p.

U.S. Department of Interior, National Park Service, March 1978, Proceedings of a Workshop on Techniques of Rehabilitation and Erosion Control in Recently Roaded and Logged Watersheds, with Emphasis to North Coastal California, Arcata, California, 88 p.

U.S. National Archives, 1978, Public contracts and property management, Code of Federal Regulations #41, 1039 p.

U.S. Department of the Interior, 1978 Technical Specifications for Watershed Rehabilitation for IFB 8480-78-2, 3 and 4, 22 p. Unpublished, on-file, Redwood National Park.